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Great Lakes Inventory & Monitoring Network

Process and Results of Choosing and Prioritizing Vital Signs for the Great Lakes Inventory and Monitoring Network

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Abstract: The National Park Service (NPS), Great Lakes Inventory and Monitoring Network is responsible for designing a long-term ecological monitoring program for nine national park units in a four state area around the western Great Lakes. The program is part of a national effort by the NPS to monitor key natural resources, termed Vital Signs, in parks around the country. This report documents the results and process the Great Lakes Inventory and Monitoring Network used to determine which resources to monitor in the nine parks. The Network and its partner parks selected and prioritized 48 Vital Signs for long-term monitoring. High priority Vital Signs include water quality, invasive species, terrestrial plants, bird communities, and land cover/land use.

INTRODUCTION

The National Park Service (NPS) has instituted a program to inventory and monitor natural resources at approximately 270 NPS parks[1] across the nation (Fancy 2004). To facilitate this program, 32 "Networks" were formed, each comprised of parks that share common management concerns and geography. The Great Lakes Inventory and Monitoring Network (hereafter, GLKN or the Network) is composed of nine national park units in Minnesota, Wisconsin, Michigan, and Indiana.

The goal of the NPS program is to identify and monitor ecological indicators, referred to by the NPS as "Vital Signs," of park ecosystem health. Vital Signs are defined as a select group of attributes that are particularly rich in information needed for understanding and managing NPS areas.

Specifically, the NPS goals for Vital Signs monitoring are to:

- Determine status and trends in selected indicators of park ecosystems that will help managers make better-informed decisions and work more effectively with other agencies and individuals.
- Provide early warning of abnormal conditions and impairment of selected resources to promote effective mitigation and reduce management costs.
- Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for more altered environments.
- Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.
- Provide a means of measuring progress towards certain NPS performance goals.

[1] The terms "parks" and "units" are used synonymously in reference to National Parks, National Monuments, National Lakeshores, National Riverways and other designated areas administered by the National Park Service.

The Great Lakes Network received funding to plan the long-term ecological monitoring portion of the program in fiscal year 2002. This report summarizes the process used by GLKN to generate and refine a list of candidate Vital Signs for long-term ecological monitoring at the nine units.

METHODS

In September 2001, the GLKN Technical Committee (hereafter "Committee"), consisting of one representative from each of the nine units, and the Midwest regional and Great Lakes Network inventory and monitoring coordinators, laid out a plan for determining Vital Signs. The plan called for scoping workshops with park staff to generate lists of monitoring issues and questions, development of conceptual models to examine important ecosystem attributes and linkages, focus workshops to get input and review from scientists, and an iterative process of park management and scientific review (Fig. 1). The Network stated a desire to emphasize Vital Signs that were common to all or most of the nine units (Fig. 2) in order to maximize the efficiency of a centralized monitoring staff. Further, GLKN envisioned that the Vital Signs would include indicators that the Network would monitor and some that are already being monitored by the nine units and other partners. This process and vision for the program was recommended by the Technical Committee and adopted by the GLKN Board of Directors. The Board, made up of four superintendents from the nine units and the Midwest regional and Great Lakes Network inventory and monitoring coordinators, has ultimate decision-making authority over the GLKN program.

Identifying and selecting Vital Signs was accomplished via the following seven steps, described more fully below:

1. Conduct park scoping workshops and gather partner information
2. Develop conceptual models of park ecosystems
3. Draft a candidate Vital Signs list
4. Refine the candidate list and assign initial priorities
5. Get peer review of the Vital Signs selection process
6. Conduct focus workshops for peer review of the candidate Vital Signs
7. Final deliberations and prioritization

Step 1 - Park scoping and information gathering

The Great Lakes Network began identifying and prioritizing Vital Signs in January of 2002 (Table 1). The first step was to hold scoping workshops at each of the nine parks, a process that has been described more fully elsewhere (Route 2003). At these workshops, GLKN informed park staff about program goals, examined what they and their partners were already monitoring, and elicited their thoughts on future monitoring needs. Natural resource staff and managers then grouped and prioritized potential monitoring efforts into themes and developed monitoring questions around them. The discussion was captured in Excel spreadsheets that were projected on-screen so that participants could view and discuss the list interactively. This helped ensure accuracy of note taking and enabled GLKN to provide the results to park staff immediately after the meeting.

After park scoping, GLKN staff contacted colleagues and other agencies regarding regional monitoring efforts. The Network collected information on the parameters being monitored, duration of study, and contact information for stewards of the data.

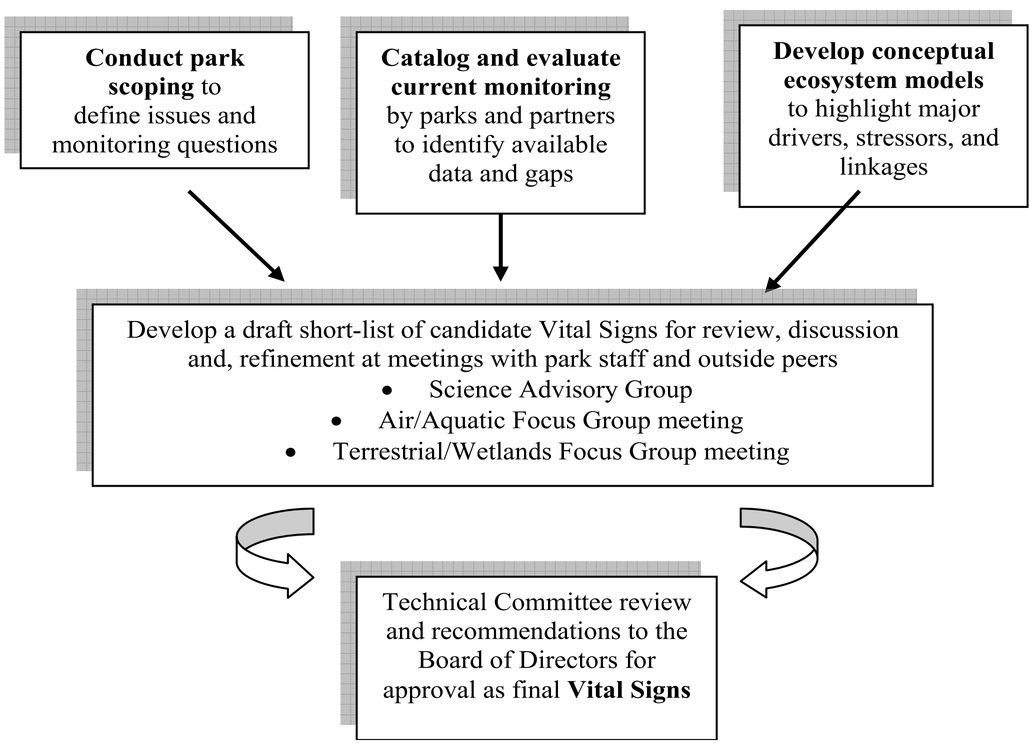

Figure 1. Box and arrow diagram showing the Great Lakes Inventory and Monitoring Network's process of defining issues, gathering information, and drafting a list of candidate indicators for review by park staff and other subject-matter experts.

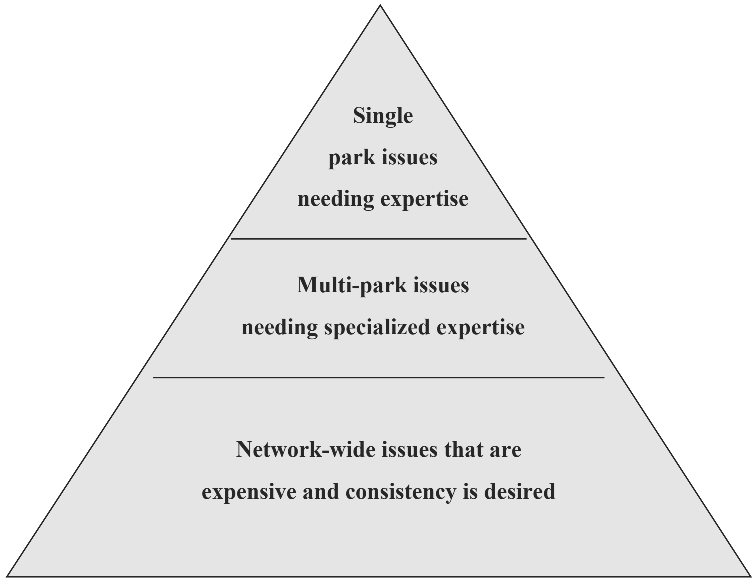

Figure 2. Effort pyramid showing the envisioned application of funding and staff-time towards monitoring in parks of the Great Lakes Inventory and Monitoring Network. Network-wide issues that are too expensive for individual parks to fund and that would greatly benefit from consistent data collection would comprise the largest share of the Network's effort (base of the pyramid). Less would be expended on single park issues except where specialized expertise is critical. Each park's monitoring, research, and management efforts would benefit, however, from the core monitoring being conducted by the Network.

Step 2 – Develop conceptual models

Following park scoping workshops GLKN commissioned the development of conceptual models to examine major ecosystems and processes in the nine units. The Committee selected six models at their October 2002 meeting: Great Lakes, Large Rivers, Inland Lakes, Wetlands, Northern Forests, and Geophysical Processes. Network staff found authors with expertise in the subject ecosystem and asked them to follow a prescribed outline to identify, describe, and diagram major ecosystem drivers, stressors, attributes, measures, linkages, and monitoring questions. All models were peer-reviewed, refereed, and published as an in-house technical report (Gucciardo et al. 2004).

Table 1. Summary of meetings and workshops held by the Great Lakes Inventory and Monitoring Network to develop a process and then choose and prioritize Vital Signs.

Date(s)	Event/Place	Participant group	Results(s)
September 18-20, 2001	Fall Technical Committee meeting, Ashland, WI.	Eleven-member Technical Committee representing each park and the regional and Network coordinators.	Agreed on the park scoping process to identify monitoring issues and questions; recommended a vision for effective monitoring (effort pyramid).
November 5, 2001	Fall Board of Directors meeting, Delavan, WI.	Five-member Board including three park superintendents and the regional and Network coordinators.	Adopted the Network Charter and the park scoping process as recommended by the Technical Committee.
January – May, 2002	Scoping workshops held at each of the nine park units.	Attended by 150 NPS staff, local science partners, and Network staff.	Informed park staff, developed lists of monitoring issues, grouped and prioritized issues into monitoring themes, and developed initial monitoring questions.
April 3-4, 2002	Spring Technical Committee meeting, Marquette, MI.	Eleven-member Committee and Network staff.	Recommended the process for refining Vital Signs through models and science review panels; determined which conceptual models should be developed.
September 5 - 6, 2002	Fall Board meeting, Ashland, WI.	Six-members including four park superintendents and the regional and Network coordinators.	Reviewed and adopted the process for refining Vital Signs as recommended by the Technical Committee.
October 8-10, 2002	Fall Technical Committee meeting, Isle Royale NP, MI.	Eleven-member Committee and Network staff.	Developed draft Network-specific provisos to the Servicewide goals for monitoring.
April 8-9, 2003	Joint Technical Committee and Board meeting, Ashland, WI.	Eleven-member Committee, six-member Board and Network staff.	Reviewed and adopted Network provisos to the Servicewide goals for monitoring.
June – October, 2003	Development of conceptual models, at various locations.	Eight NPS and partner scientists with backgrounds in important ecosystems.	Developed six stressor-based conceptual models to highlight critical processes, stresses, linkages, and potential indicators.
September 15-19, 2003	Staff meetings, Ashland, WI.	Five members of the Great Lakes Network staff.	Developed an initial short-list of potential Vital Signs for deliberation by the Technical Committee.
October 7-8, 2003	Technical Committee meeting, Madison, WI.	Eleven-member Committee and Network staff.	Agreed on criteria and then refined and scored the draft list of candidate Vital Signs developed by Network staff.
October 9, 2003	Board of Directors meeting, St. Paul, MN.	Six-member Board.	Reviewed initial Vital Signs list and agreed to the criteria and general process for refining the list.
October 29, 2003	Science Advisory Group meeting, Ashland, WI.	Ten scientists experienced in long-term monitoring and statistics; Network staff.	Received peer-review of the selection process and a straw poll on “best bet” and “no go” Vital Signs.
February 3-4, 2004	Aquatic/Air Focus Group meeting, Marine on St. Croix, MN.	Fourteen aquatic and air resource scientists and Network staff.	Refined the draft Vital Signs list, scored them on ecological significance and measurability, and began listing metrics.
February 18-19, 2004	Terrestrial/Wetland Focus Group meeting, Ashland, WI.	Nine terrestrial and wetlands scientists and Network staff.	Refined the draft Vital Signs list, scored them on ecological significance and measurability, and began listing metrics.
March 1-12, 2004	Park staff meetings held at each park.	Key natural resource and management staff at each park.	Re-scored each Vital Sign based on information from Science Advisory Group and Focus Groups.
March 18, 2004	Spring Technical Committee meeting, St. Paul, MN.	Eleven-member Committee and Network staff.	Reviewed and adopted the Vital Signs list with recommendations to flesh out specific questions and address park needs under certain Vital Signs (i.e. T&E).
April 8, 2004	Spring Board meeting via conference call.	Six-member Board.	Adopted the draft Vital Signs list and initial prioritization as recommended by the Technical Committee.

Step 3 - Develop a candidate list of Vital Signs

Network staff used the conceptual models, results of park scoping workshops, and information on partner monitoring to draft a list of candidate Vital Signs. Initially, GLKN considered 80 indicators under development by the US Environmental Protection Agency (EPA) and Environment Canada (EC) for assessing progress towards goals of the Great Lakes Water Quality Agreement (Bertram and Stadler-Salt 2000). We used some of these indicators, but many did not apply to the nine parks so that the draft candidate list drew most heavily from the park scoping workshops and the conceptual models.

Step 4 - Refine the candidate list and assign initial priorities

In October 2003, the Committee adopted criteria and weighting factors for scoring Vital Signs (Table 2). Candidate indicators were scored on: “Management Significance” weighted at 40%, “Ecological Significance” weighted at 40%, “Measurability/ Sensitivity” weighted at 20%, and “Legal/Policy Mandate” as a tie breaker. Each criterion was scored by participants as either very high (5 points), high (4), medium (3), low (2), very low (1), none (0), or null in regards to a candidate’s value or performance as an indicator. Management and Ecological Significance were weighted equally because ecological integrity is a primary management concern in all national parks (NPS 1991). Management Significance scores were reserved for parks since they will ultimately use the monitoring data to make management decisions. Ecological Significance was scored by both parks and Focus Groups; however, Focus Group scores were provided to parks as peer review and not used in the final score calculations. The criterion Measurability/ Sensitivity was scored only by the Focus Groups because they had the best knowledge of the quantitative measures and ecological linkages critical to this criterion. While 20% seems low, GLKN believed more in-depth information would surface when available data was analyzed and protocol development began. Thus, a low weighting here would allow GLKN to keep a Vital Sign viable until more complete information became available. For each criterion, GLKN developed four or five statements that would help individuals apply the criteria consistently.

After adopting the criteria, the nine park representatives on the Committee made their first effort at scoring each Vital Sign based on “Management Significance”, “Ecological Significance”, and “Legal/Policy Mandate”. (Network staff facilitated and participated in discussions but did not score Vital Signs.) The “Legal/Policy Mandate” criterion was intended as a tie breaker, but was not applied. Nonetheless, legal concerns and agency mandates, such as sensitive and harvested species, were considered under Management Significance (see bullets under criterion 1 in Table 2). The criteria, scoring process, and initial scores were brought to the Board for consideration in October 2003.

Step 5 – Review of selection process

In January 2004, GLKN formed a 10-member Science Advisory Group (SAG) to get peer review of our overall program with emphasis on the process of choosing and prioritizing Vital Signs. This advisory group includes scientists with many years of experience in long-term ecological monitoring programs and experts in focal resources of the Great Lakes and upper Mississippi River basins (Appendix A). Prior to the meeting, group members received background information on the program, objectives of the meeting, an outline of the selection process, the candidate Vital Signs list, and the criteria for scoring them. Due to lack of time, SAG members did not use the criteria to score each Vital Sign, but they identified their top five "best bets" and those they felt should not be part of GLKN's monitoring. This straw poll was provided to the Committee as a peer review of their initial scores from step 4.

Table 2. Criteria and weighting factors used to prioritize Vital Signs for the Great Lakes Inventory and Monitoring Network, 2003 - 2004. Criteria were condensed from Dale and Beyeler (2001).

Each of the following, except "legal /policy mandate" was used by participants who ranked Vital Signs as very high (5), high (4), medium (3), low (2), very low (1), none (0), or null in regards to its value as an indicator. The value "none" equaled zero in summary calculations, while null was valueless (i.e., there was no opinion). The criterion "legal mandate/policy mandate" was ranked as very high, high, or none depending on whether there were federal/state mandates, federal/state policies, or no mandates/policies respectively.

1) Management significance (Weight = 40%; scored only by park staff)
   - Has direct application to one or more management decisions or helps assess management actions.
   - Helps anticipate or predict impending change in an important resource that could be averted by management action.
   - Contributes to increased understanding of important resources or ecological processes that ultimately leads to better management.
   - Data are of high public interest.
   - Involves resources that are harvested, consumed, endemic, alien, threatened, endangered, or of special concern.

2) Ecological significance (Weight = 40%; scored by both park staff and focus workshop participants; however, focus workshop participant scores were used only as a recommendation to park staff)
   - Has a strong defensible linkage with the resource it is intended to represent.
   - The resource or process the attribute represents has high ecological importance based on conceptual models and ecological literature.
   - The attribute responds to change in a predictable, ecologically explainable manner.
   - The attribute is integrative over time and provides ecological context or supporting evidence to data from other indicators being monitored by the park or others.

3) Legal/Policy mandate (No weighting - tie breaker; scored only by park staff)
   - Scored as "5" if mandated by federal law, "4" if by state law or NPS policy, and "n/a" if no laws or mandates apply.

4) Measurability and sensitivity (Weight = 20%; scored by focus workshop participants only)
   - Reliable and effective methods exist for collecting and analyzing the data in a consistent and repeatable manner.
   - The cost of collecting a significant sample is not prohibitive.
   - Measurements are sensitive to change such that a trend will be apparent if present (high signal to noise ratio).
   - Human errors in measurement are either low or can be explained.

Step 6 - Conduct focus workshops

In February of 2004, GLKN held two workshops – one focusing on Vital Signs related to aquatic and air resources, and one focusing on terrestrial and wetland resources. Participants were selected for their knowledge and experience with monitoring natural resources in the region (Appendix B). Prior to each workshop participants received background information on the program, meeting objectives, web access to the conceptual models, the candidate Vital Signs list, and the criteria for scoring them. At the meeting, each Vital Sign was discussed to ensure a common understanding; participants could refine and add to the list, but could not delete Vital Signs. The ecological significance, measurability, and sensitivity of each Vital Sign were discussed. The discussion was captured in an Excel worksheet that was displayed on screen for everyone to follow and ensure accuracy; extensive meeting minutes were also taken.

At the end of two 1½ day meetings GLKN asked participants to score each Vital Sign for "Ecological Significance, and "Measurability/ Sensitivity", separately, using the criteria in Table 2. The Network originally intended to average Ecological Significance scores across both the Committee and the Focus Groups. However, the number of participants in the Focus Groups (23) would have swamped evaluations by the nine park representatives. To ensure park staff views were well represented, yet the recommendations of Focus Groups were considered, GLKN provided Ecological Significance scores and notes from the meetings to the parks for consideration in adjusting their scores.

Step 7 - Final deliberations and prioritization

The Network summarized scores and discussions from the Science Advisory Group and the two Focus Groups and provided them to the park representatives for consideration (Appendix D). For each Vital Sign, GLKN provided information on suggested changes to the candidate list, potential measures, important discussion points and linkages, and average scores. Park representatives then engaged staff at their park, provided this new information and used it to confirm or adjust their original scores. Parks were given two weeks to review the information, adjust their scores, and return the results to the Network.

Network staff calculated draft-final scores as:

Score = (MS x 0.4) + (ES x 0.4) + (SM x 0.2)

Where: MS = the average of the park scores for Management Significance
ES = the average of the park scores for Ecological Significance
SM = the average of focus workshop participant scores for Sensitivity and Measurability

Note: Park and Focus Group scores were combined in the final calculations; however, because we wanted to compare the two groups, we prorated the weighting when calculating an average score for Focus Groups in Table 6.

The Committee discussed the new scores at their March 2004 meeting and made recommendations to the Board of Directors. The Board met in April, 2004 to deliberate and make final approval.

RESULTS AND DISCUSSION

Developing the candidate Vital Signs list (steps 1 – 3)

At park scoping workshops GLKN engaged 150 park staff and local partners and developed a list of over 200 monitoring issues (Route 2003). These issues were then grouped into monitoring themes by natural resource staff at each park. For each theme, park staff noted specific monitoring questions that they felt were important for understanding and managing the parks (Appendix C). These park-specific monitoring issues can be grouped into 12 broad themes across the Network (Table 3). Six of these themes were identified by at least eight of the nine parks, but the relative importance, as measured by the proportion of natural resource staff voting for them, varied from 0% to 100%. Many of these differences are understandable. For example, Isle Royale (ISRO), as an island in Lake Superior, is relatively unaffected directly by adjacent land use; therefore, no natural resource staff felt adjacent land use was a priority for monitoring. By contrast, Pictured Rocks (PIRO) has pressing road development and logging concerns, and all natural resource staff felt land use should be monitored. Interestingly, at Indiana Dunes (INDU), where adjacent human development has fragmented the landscape and caused myriad environmental changes, only two of 10 natural resource staff identified land use as a monitoring need. This likely reflects the inability of managers at INDU, by virtue of Congressional Act, to affect land use around them (R. Knutson, personal communication). It is important to note, however, that most parks within the GLKN have small natural resource staffs. Individual bias and the lack of expertise in numerous complex issues obviously affected the outcome. On its own, this park-by-park prioritization is inconclusive and demonstrates the need for a peer review process that allows parks to reconsider their monitoring priorities.

Park scoping was an important beginning to the iterative process of refining the Network's Vital Signs. It helped engage park staff, grounded the process in the parks where monitoring will be implemented, and helped Network staff better understand the issues. In addition, it helped GLKN identify the expertise needed for conceptual models and for the Science Advisory and Focus Groups. Most importantly, the themes and monitoring questions brought out at these scoping workshops, together with the conceptual models (see below), formed the basis of the Vital Signs list.

During the scoping workshops, 214 ongoing monitoring projects were identified and cataloged at the nine parks (Route 2003). These ongoing efforts did not affect the final Vital Signs list because the park scoping process did not discriminate between currently monitored and ongoing projects. The information on ongoing monitoring will be valuable during the protocol development and implementation phase, when Network funds and staff are allocated to monitor as many Vital Signs as can be done effectively.

Table 3. Monitoring themes identified by participants at nine scoping workshops at national park units in the Great Lakes Inventory and Monitoring Network. Rank scores and averages (Avg.) are based on votes by participants.

	Great Lakes Network Parks[2,3]										
Monitoring theme[1]	VOYA	GRPO	ISRO	APIS	PIRO	SLBE	INDU	SACN	MISS	Avg	No. parks
Water quality including an index to aquatic integrity.	1.00	1.00	1.00	0.60	0.75	0.83	0.70	0.88	0.42	0.80	9
Landscape change, including land use and habitat fragmentation.	0.57	0.67	0.00	1.00	1.00	0.83	0.20	0.75	0.67	0.63	8
Exotic species, both aquatic and terrestrial.	0.71	0.67	1.00	0.40	0.75	0.50	0.70	0.38	0.50	0.62	9
Threatened, endangered and rare species of animals and plants.	0.14	0.67	0.67	0.80	0.50	0.67	0.90	0.25	0.58	0.58	9
Forest health (FHM) and habitat quality.	0.57	0.67	0.50	0.60	0.50	0.83	0.30	0.50	0.25	0.52	9
Human activities in the park including camping, trail use, facilities etc..	0.29	0.67	0.17	0.20	0.25	0.00	0.20	0.25	0.42	0.27	8
Weather / climate change.	0.14	0.00	0.17	0.40	0.25	0.00	0.10	0.00	0.00	0.12	5
Geologic processes - sandscapes, beach erosion.	0.00	0.00	0.00	0.40	0.00	0.50	0.00	0.00	0.17	0.12	3
Air quality / pollution.	0.14	0.00	0.17	0.20	0.00	0.00	0.30	0.00	0.00	0.09	4
Harvested species, fish, game, plants.	0.29	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.09	2
Ecosystem processes including nitrogen cycling and disease.	0.00	0.00	0.67	0.00	0.00	0.00	0.10	0.00	0.00	0.09	2
Aquatic high diversity areas including wetlands and river sloughs.	0.14	0.00	0.00	0.20	0.00	0.17	0.00	0.13	0.00	0.07	4

1 = Monitoring theme defined as a group of related issues or indicators that might be monitored under the umbrella of one program (i.e. water quality / aquatic integrity could include macroinvertebrates, water chemistry, lake levels, and stream flow).

2 = Participation in prioritization-setting: VOYA=7 GRPO=3, ISRO=6, APIS=5, PIRO=4, SLBE=6, INDU=10, SACN=9, MISS=12, Total= 62.

3 = Park alpha codes: VOYA= Voyageurs National Park, GRPO= Grand Portage National Monument, ISRO= Isle Royale National Park, APIS= Apostle Islands National Lakeshore, PIRO= Pictured Rocks National Lakeshore, SLBE= Sleeping Bear Dunes National Lakeshore, INDU= Indiana Dunes National Lakeshore, SACN= St. Croix National Scenic Riverway, MISS= Mississippi National River and Recreation Area.

The participants in the Vital Signs process used the six conceptual models to establish a common understanding of the major ecosystems. The Network chose stressor-based models to help link management issues (e.g., many of them are drivers or stressors) to change in the environment, and ultimately to the Vital Signs. Linking management issues and questions to the indicators being monitored is critical to the long-term support and success of any monitoring program (Maddox et al. 1999). Model authors used personal knowledge and an extensive body of literature to formulate a science-based perspective on monitoring needs irrespective of the parks. It was GLKN's intension to provide this Network-wide and science-oriented perspective to complement the park-centered and management-oriented park scoping workshops.

Network staff used the models, together with the themes and questions raised at park scoping workshops (Appendix C), to formulate a candidate list of 40 Vital Signs (Appendix E). The models helped identify additional issues, especially processes such as sedimentation, primary productivity, and trophic relations. They also validated and further highlighted the themes identified by park staff. We organized the 40 candidate Vital Signs into seven categories to facilitate discussion: Water Quality, Contaminants, Landscape/Land Use, Ecosystem Processes, Habitats, Weather/Climate, and a combination grouping called Organisms/Species/Populations/Communities. We also linked each candidate Vital Sign to supporting models and parks where it was a monitoring need (Appendix E).

Refining and prioritizing the list (steps 4 – 6)

At the October 2003 Committee meeting, the candidate list was discussed and some minor adjustments made, such as splitting "Air Quality" into a Vital Sign specifically for Air Contaminants (#7) and another for Air Quality Related Values (#10) such as smog (Table 4). The nine park representatives then spent about one hour scoring the Vital Signs, which resulted in an initial prioritized list of 40 Vital Signs.

Following this initial scoring, GLKN met with the 10-member Science Advisory Group to get their critique of the Vital Signs selection process and the candidate list. The group reviewed the draft Vital Signs and had no immediate suggestions for improvement. Each member identified their top "best bets" and those they felt should not be monitored by the Network. The Network summarized this straw poll and compared it with the Committee's initial scores as a peer review (Table 4). Examples of differences between scores include T&E species (#47), special habitats (#25), and trophic bioaccumulation (#5), which were scored relatively high by the Committee, but not well supported by the Science Advisory Group. Also, phenology (#27) and benthic invertebrates (#30) were scored relatively low by the Committee, yet had some support from the Advisory Group. Finally, weather/meteorological data (#26) and toxic concentrations in water (#8) received moderate support from the Committee, but were either highly supported or rejected, respectively, by the Science Advisory Group.

A majority (8 of 10) of the Science Advisory Group felt the process GLKN used to identify Vital Signs was valid and comparable to similar efforts they were aware of. Specifically, they approved of GLKN's efforts to get input and review from park managers and subject experts, both inside and outside of the NPS. Two members felt GLKN should have developed specific monitoring questions first and allowed these questions to lead to the Vital Signs. GLKN did this, to a degree, since it was the park-generated themes and *monitoring questions*, (Table 3, Appendix C) combined with the attributes, measures, and *monitoring questions* posed by model authors (Gucciardo et al. 2004) that formed the basis of our candidate list. We felt it would be most efficient to refine these monitoring questions after determining the final Vital Signs list. Throughout the process, most scientists and managers were comfortable discussing the Vital Signs without questions. We acknowledge, however, that specific monitoring questions must be defined before measures for each Vital Sign can be determined.

At each of the two 1 ½ day focus meetings, the groups spent approximately eight hours discussing the Vital Signs that pertained to their subject (air/aquatic or wetlands/terrestrial). The two groups added nine Vital Signs, combined four others into two, and made a few minor name changes to some Vital Signs. These changes were documented in a summary narrative (Appendix D). Participants took about one hour to score the Vital Signs on “Ecological Significance” and “Measurability/Sensitivity” (Table 5). Fourteen individuals participated in the Air/Aquatic Focus Group and nine in the Wetland/Terrestrial Focus Group. Participants had the option of not scoring a Vital Sign if they had insufficient knowledge of the resource. Additionally, two participants in the Air/Aquatic Group had to leave early and did not score the Vital Signs. Hence the number of persons scoring varied between the groups and among Vital Signs (Table 5).

Final deliberations (step 7)

Several parks (six of nine) used the peer review process to discuss and rescore the Vital Signs, while three parks were satisfied with their original scores. The new scores were presented and discussed at the spring 2004 Committee meeting. At this meeting the group also deleted one candidate Vital Sign (land-water transition zone), because it described where monitoring might occur rather than what might be monitored.

The final Vital Signs scores included adjusted park scores for Management and Ecological Significance, and the Focus Group scores for Measurability/Sensitivity (Table 6, column 1). The priority order (parks and Focus Group weighted average) changed somewhat from the first attempt at prioritization (compare with Table 4). For example, the core water quality suite, weather/meteorological data, and mammal communities Vital Signs all moved up while T&E species, toxic concentrations in water, and special habitats went down. These changes primarily reflect the addition of the Measurability/Sensitivity scores by focus groups, but also the influence of peer review on park scores. Vital Signs that consistently scored high include the core water quality suite, plant and animal exotics, land cover/land use-coarse scale, and terrestrial plant communities.

Network staff facilitated all of the meetings, authored and/or reviewed the conceptual models, and drafted the first candidate Vital Signs list, but did not participate in scoring. This is because we wanted the process to reflect the park’s perspectives as much as possible. It is essential, however, to have buy-in from those who will implement the program. To see how Network staff opinions compared to parks and partners, Network staff also scored the Vital Signs (Table 6, column 3). Network staff scores reflect opinions, on a scale of 1 to 5 with five being highest, on ecological/managerial importance, measurability/sensitivity, and feasibility for implementation.

Table 4. Initial scores by park representatives on the Technical Committee, and results of a straw poll of the Science Advisory Group, on the candidate Vital Signs for the Great Lakes Network. Vital Signs are listed in order of the overall Committee average. Un-numbered Vital Signs are those that were later dropped or combined; see text.

		Technical Committee[1]				Science advisory[2]	
# /	Candidate Vital Sign	No. parks voting	Average Mgt Significance	Average Ecol Significance	Overall average	Best bets	Don't bother
42	plant and animal problem species	9	4.4	4.3	4.4	3	0
47	T&E species	9	4.6	3.7	4.1	1	0
45	terrestrial plant communities	9	3.8	4.1	3.9	6	0
2	advanced water quality suite	9	3.7	4.1	3.9	3	1
40	bird communities	9	3.6	4.2	3.9	3	0
1	core water quality suite	9	3.6	3.9	3.7	7	0
	land cover fine scale	9	3.8	3.6	3.7	2	0
25	special habitats	9	3.3	3.9	3.6	0	1
	land cover coarse scale	9	3.4	3.8	3.6	5	0
39	herps	9	2.9	4.1	3.5	2	0
	land use coarse scale	9	3.3	3.4	3.4	3	0
5	high trophic bioaccumulation	9	3.1	3.6	3.3	1	4
48	biotic diversity	9	2.7	3.9	3.3	1	1
19	succession	9	2.9	3.7	3.3	0	1
28	fish communities	9	2.8	3.8	3.3	5	0
14	water level fluctuations	9	2.9	3.6	3.2	3	0
21	geological processes	9	3.1	3.3	3.2	0	1
46	aquatic plant communities	9	2.6	3.8	3.2	4	0
10	air quality (AQRV)	9	3.1	3.2	3.2	0	1
26	weather, meteorological data	9	2.2	4.0	3.1	5	0
	land use fine scale	9	3.3	2.9	3.1	2	0
8	toxic concentrations in water	9	3.2	3.0	3.1	1	5
20	trophic relations	9	2.6	3.6	3.1	0	1
44	harvested species	9	3.2	2.9	3.1	0	0
41	mammal communities	9	2.7	3.3	3.0	2	0
	land-water transition zone	9	2.3	3.6	2.9	1	1
31	mussels & snails	9	2.7	3.2	2.9	0	0
4	sediment analysis	9	2.6	3.3	2.9	0	2
34	terrestrial invert communities	9	2.2	3.7	2.9	0	0
6	health, growth and reproductive success	9	2.8	3.0	2.9	1	2
16	stream dynamics	8	2.9	2.9	2.9	0	1
27	phenology	9	1.7	3.6	2.6	3	0
7	air quality	9	2.1	3.0	2.6	0	4
24	soil characteristics	9	1.8	3.2	2.5	0	4
32	sponges	7	2.0	3.0	2.5	0	2
15	nutrient dynamics	9	1.8	3.1	2.4	0	2
18	primary productivity	9	1.3	3.4	2.4	2	2
30	benthic inverts	9	1.6	3.1	2.3	3	0
36	phytoplankton	9	1.3	2.9	2.1	0	1
33	zooplankton	9	1.2	3.0	2.1	0	1

1= Technical Committee refers here to the 9 park representatives who scored Vital Signs in regard to management significance and ecological significance for their park.

2= The Science Advisory Group consists of 10 scientists with experience in long-term monitoring. They were polled as to their opinion on the value of each Vital Sign for monitoring in parks of the Network.

Table 5. Average Vital Sign scores from scientists participating in two Focus Groups for the Great Lakes Network. Vital Signs are listed in order of the overall score. For this comparison, the overall score is the average of ecological significance weighted at 66.6% and measurability/sensitivity at 33.3%.

		Air/Aquatic Group				Terrestrial/Wetland Group				
		Ecological Significance		Sensitivity Measurability		Ecological Significance		Sensitivity Measurability		
# /	Candidate Vital Sign	Avg	n	Avg	n	Avg	n	Avg	n	Overall score
1	core water quality suite	4.5	11	4.7	11	4.6	9	4.4	9	4.5
2	advanced water quality suite	4.7	11	4.2	11	3.6	9	2.8	9	3.9
3	aquatic pathogens	1.9	12	2.9	12					2.2
4	sediment analysis	4.5	12	3.8	12					4.3
5	trophic bioaccumulation	4.4	11	3.7	11	3.3	9	2.4	9	3.6
6	health, growth and reproductive success	3.7	10	1.8	10	2.7	9	2.9	9	2.9
7	air contaminants**	4.0	11	2.5	11	4.1	9	3.4	9	3.7
8	toxic concentrations in water	2.6	11	2.1	10					2.4
9	toxic concentration in sediments	3.8	11	3.2	11					3.6
10	other air quality-related values	1.6	8	2.6	7	1.9	9	2.9	9	2.1
11	soundscapes, light pollution	3.3	4	3.0	3	1.4	9	1.6	8	2.4
12	land cover/land use coarse scale** (a)	4.4	10	4.3	8	4.9	9	4.0	9	4.5
13	land cover/land use fine scale** (b)	3.5	10	3.1	8	4.4	9	3.2	9	3.7
14	water level fluctuations	4.7	11	4.2	10	4.2	9	3.6	9	4.3
15	nutrient dynamics, biogeochemistry**	3.6	10	2.3	10	3.0	9	1.7	9	2.9
16	fluvial geomorphology**	3.9	8	3.5	8	3.4	8	3.0	8	3.5
17	aeolian, lacustrine geomorphology					3.6	8	2.8	8	3.3
18	primary productivity	4.2	10	1.4	9	3.0	9	2.7	9	3.1
19	succession (forests, wetlands)	2.4	7	1.7	7	3.8	9	3.4	9	2.9
20	trophic relations	3.1	9	1.1	8	3.0	9	3.0	9	2.7
21	geological processes	2.5	10	2.8	7	2.9	8	3.3	8	2.8
24	soil**	3.6	9	3.8	9	3.5	8	2.4	8	3.4
25	special habitats	3.7	11	2.6	10	3.7	3	3.3	3	3.4
26	weather, meteorological data	4.5	10	4.8	10	4.6	9	4.7	9	4.6
27	phenology	3.6	10	3.4	10	3.9	9	3.6	9	3.7
28	fish communities	4.5	10	3.7	10	3.7	9	3.0	9	3.8
29	IBI	3.4	10	2.4	10					3.1
30	aquatic macro inverts**	4.6	10	3.1	10	3.7	9	2.4	9	3.7
31	mussels & snails	4.3	11	2.8	11					3.8
32	sponges	2.3	9	1.6	9					2.1
33	zooplankton	4.2	11	2.7	11					3.7
34	terrestrial invert communities**	2.0	2	3.0	1	3.2	9	2.0	9	2.6
35	terrestrial pests, pathogens**					3.9	9	3.0	8	3.6
36	algae**	4.1	10	2.8	10	2.7	6	2.3	6	3.1
37	diatoms	4.3	11	3.9	11					4.2
38	lichens & fungi					2.6	9	1.9	9	2.3
39	amphibian & retiles (herptiles)	3.8	10	2.6	10	3.9	9	3.0	9	3.5
40	bird communities	3.6	10	4.0	10	3.9	9	3.4	9	3.7
41	mammal communities	3.8	10	3.4	9	3.2	9	2.7	9	3.4
42	plant and animal exotics/invasives	4.7	11	3.9	11	4.9	8	3.6	8	4.4
43	native spp out of balance** (c)	2.8	9	2.9	9	3.9	9	3.1	9	3.2
44	harvested species	4.0	9	3.2	10	2.8	9	2.7	9	3.2
45	terrestrial plant communities					4.4	9	3.6	9	4.1
46	aquatic/wetland plant communities**	4.4	10	3.4	9	4.6	9	3.6	9	4.1
47	T&E species	3.9	10	2.3	10	2.7	9	2.1	9	2.9
48	biotic diversity	1.8	8	1.3	8	2.1	7	2.6	7	2.0

** This indicator was added or the description was revised during focus workshops; see narrative.

a) The Technical Committee scored 'land cover coarse scale' and 'land use coarse scale' separately, but these were combined by focus groups. The Committee's two scores were averaged for comparison with the other groups.

b) The Committee scored 'land cover fine scale' and 'land use fine scale' separately, but these were combined by focus groups. The Committee's two scores were averaged for comparison with the other groups.

c) The Committee considered exotic species as part of problem species during this first scoring.

Table 6. Rank-order of combined park and focus group weighted scores, focus group weighted scores, and Network staff scores for Vital Signs in the Great Lakes Network. Scores include ties and are not directly comparable since different criteria were used; see text for discussion. Gray-shaded Vital Signs are in the top 50% for that group. Vital Signs are in order of the parks and focus groups weighted average.

# /	Candidate Vital Signs	Parks and focus groups weighted average	Focus groups weighted average	Network staff score
42	plant and animal exotics	4.3	4.4	4.3
1	core water quality suite	4.3	4.5	4.8
45	terrestrial plants	4.0	4.1	4.0
40	bird communities	3.9	3.7	3.5
43	problem species	3.8	3.2	4.0
12	land use / land cover coarse scale	3.8	4.5	4.8
47	T&E species	3.7	2.9	2.5
14	water level fluctuations	3.6	4.3	4.8
2	advanced water quality suite	3.6	3.9	4.3
46	aquatic/wetland plant communities	3.6	4.1	4.0
26	weather, meteorological data	3.5	4.6	5.0
39	amphibians & reptiles (herptiles)	3.5	3.5	3.8
41	mammal communities	3.5	3.4	3.0
28	fish communities	3.5	3.8	3.0
13	land use / land cover fine scale	3.5	3.7	4.3
5	trophic bioaccumulation	3.4	3.6	3.3
25	special habitats	3.4	3.4	3.0
31	mussels & snails	3.3	3.8	3.8
44	harvested species	3.3	3.2	2.5
4	sediment analysis	3.3	4.3	3.0
35	terrestrial pests, pathogens	3.3	3.6	2.0
19	succession (forests, wetlands)	3.2	2.9	2.7
9	toxic concentrations in sediments	3.2	3.6	2.7
48	biotic diversity	3.1	2.0	2.0
16	fluvial geomorphology	3.1	3.5	3.0
20	trophic relations	3.0	2.7	1.8
7	air contaminants	3.0	3.7	3.0
27	phenology	3.0	3.7	3.8
8	toxic concentrations in water	2.9	2.4	2.0
34	terrestrial invert communities	2.9	2.6	2.5
24	soil	2.8	3.4	2.3
6	health, growth and reproductive success	2.8	2.9	2.8
30	benthic invertebrates	2.8	3.7	3.5
37	diatoms	2.7	4.2	3.8
3	aquatic pathogens	2.7	2.2	2.0
10	air quality related values (AQRV)	2.6	2.1	2.0
36	algae	2.6	3.1	2.0
38	lichens & fungi	2.5	2.3	2.3
15	nutrient dynamics, biogeochemistry	2.5	2.9	1.7
21	geological processes	2.5	2.8	2.0
17	aeolian, lacustrine geomorphology	2.5	3.3	2.0
18	primary productivity	2.5	3.1	2.3
29	IBI (index of biotic integrity)	2.4	3.1	1.5
33	zooplankton	2.4	3.7	2.5
11	soundscapes, light pollution	2.3	2.4	2.3
32	sponges	2.1	2.1	2.0

The three scores for each Vital Sign in Table 6 arose from unique perspectives and varying criteria. The "parks and focus groups weighted average" combines management and ecological significance as well as measurability and sensitivity of the Vital Sign. The "focus groups weighted average" reflects ecological significance as well as measurability and sensitivity, but not management significance. The "Network staff scores" reflect an overall opinion on all criteria, and perhaps a unique consideration for the feasibility and cost of implementation. Even with these different views and criteria, considerable agreement for the top 50% (gray cells for each group in Table 6) emerged. Differences, such as low scores by Focus Groups and Network staff for T&E and harvested species, reflect their relatively low ecological significance and the difficulties in measuring them (see within group scores in Table 5). Yet they are of high management significance to parks and their final scores reflect that concern. A further reason for differences may be that park staff, including Committee members, generally did not attend the advisory or focus meetings. Travel costs, staff time, and effective group size were limiting factors for participation. Conceivably, if all Committee members had been present for all meetings, our scores would have been even closer.

The Committee and Board met at separate spring 2004 meetings and respectively recommended and adopted the prioritized "park and focus groups weighted average" list in Table 6. They both noted, however, a need to refine certain Vital Signs to reflect specific needs of individual parks. For example, the "T&E" Vital Sign (#47) eventually needs to reflect different measures (i.e., species) of concern for each park. It was agreed that the Network would develop specific questions, objectives, and protocols for Vital Signs in the general order of the final scores; however, exceptions would be allowed for efficiencies gained by grouping Vital Signs in protocol packages and when costs can be shared by partnering with other agencies.

Ultimately, the Network, including the partner parks through the Technical Committee and Board of Directors, will struggle with the logistics and costs of monitoring all of the Vital Signs. The Network will need to consider the original vision for efficient implementation (Fig. 2) and determine how much effort is put towards measuring each of these Vital Signs. T&E species is an example of a Vital Sign that could take considerable funding when one considers the variety of species (plants to animals) across the individual parks.

This 'Final' Vital Signs list is the Network's best attempt at narrowing the potential indicators, however, it will likely change as monitoring questions and measures are further defined, and as protocols, logistics, and costs are better understood.

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APPENDIX A

MEMBERS AND AFFILIATIONS OF THE SCIENCE ADVISORY GROUP (SAG) FOR THE GREAT LAKES INVENTORY AND MONITORING NETWORK.

Name	Affiliation	Area of professional expertise
Phyllis Adams, Ph.D.	NPS-Midwest Region Regional Inventory & Monitoring Coordinator	Forest monitoring
Jon Bartholic, Ph.D.	Michigan State University Professor, Resource Development and Director, Institute of Water Research	Watersheds and information systems
Jerry Belant, Ph.D.	NPS-Pictured Rocks National Lakeshore Center Director, Pictured Rocks Science Center and Terrestrial Ecologist	Wildlife ecology
Paul Bolstad, Ph.D.	University of Minnesota-Twin Cities Associate Professor, College of Natural Resources	Forest ecology, spatial data analysis, and spatial ecology and modeling
Thomas Drummer, Ph.D.	Michigan Technological University Associate Professor, Dept. of Mathematical Sciences	Statistical ecology, model-based sampling, and application of statistics to wildlife ecology
Tim Kratz, Ph.D.	Long Term Ecological Research-North Temperate Lakes (LTER-NTL) Site Director and Aquatic Ecologist	Aquatic ecology, biogeochemistry, and ecosystem ecology
Kirk Lohman, Ph.D.	USGS-Upper Midwest Environmental Sciences Center Lab Director, Geospatial Sciences & Decision Support Lab	Landscape ecology, remote sensing
Gerald Niemi, Ph.D.	University of Minnesota – Duluth and Natural Resources Research Institute Director, Center for Water and the Environment, NRRI, Professor, Dept. of Biology	Avian research and monitoring, Great Lakes ecological indicators and monitoring
Walt Sadinski, Ph.D.	USGS-Upper Midwest Environmental Sciences Center Research Ecologist and Program Leader for USGS Amphibian Research and Monitoring Initiative	Amphibian research and monitoring
Janet Keough, Ph.D.	US Environmental Protection Agency – Environmental Effects Research Lab, Duluth Director and Aquatic Ecologist	Great Lakes aquatic ecology and monitoring

APPENDIX B

MEMBERS AND AFFILIATIONS OF THE FOCUS GROUPS WHO PARTICIPATED IN REFINING AND SCORING VITAL SIGNS FOR THE GREAT LAKES INVENTORY AND MONITORING NETWORK.

Air and Aquatic Resources Group:

Name	Affiliation	Area of professional expertise
Tonnie Maniero	NPS-Air Resources Division Air Resource Field Specialist	Air resources
David Pohlman	NPS-Air Resources Division Regional Air Quality Coordinator	Air resources
Jim Wiener, Ph.D.	University of Wisconsin-LaCrosse Distinguished Professor	Aquatic ecotoxicology, biogeochemistry of mercury and heavy metals.
Randy Ferrin	NPS-St. Croix National Scenic Riverway Chief, Resource Management Division	Air and water resources
Brenda Moraska Lafrancois, Ph.D.	NPS-Midwest Region Great Lakes Area Aquatic Ecologist	Aquatic ecology
Jay Glase	NPS-Midwest Region Fishery Biologist	Aquatic biology
Ken Lubinski, Ph.D.	USGS-Upper Midwest Environmental Sciences Center Aquatic Scientist	River ecology, monitoring, and modeling
Glenn Guntenspergen, Ph.D.	USGS-Patuxent Wildlife Research Center Research Ecologist	Wetland, landscape, and urban ecology research
Larry Kallemeyn, Ph.D.	USGS- International Falls Field Research Station Station Leader	Aquatic biology
Lora Loope	NPS-Pictured Rocks National Lakeshore Aquatic Ecologist	Aquatic biology, primary producers, diatoms
Dan Engstrom, Ph.D.	Science Museum of Minnesota Director, St. Croix Watershed Research Station and Adjunct Professor, Geology and Geophysics, University of Minnesota	Paleolimnology, sediment geochemistry
Richard Axler, Ph.D.	University of Minnesota-Duluth Natural Resource Research Institute Senior Research Associate, Center for Water and the Environment and Director, Central Analytical Laboratory	Water quality management and restoration
Joe Mayasich, Ph.D.	University of Minnesota-Duluth Natural Resource Research Institute Research Associate, Center for Water and the Environment	Aquatic biology, ecological risk assessment

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Gary Vequist	NPS-Midwest Region Associate Regional Director	Aquatic resources

Focus Group Participants: Terrestrial and Wetlands

Name	Affiliation	Area of professional expertise
JoAnn Hanowski	University of Minnesota-Duluth Natural Resource Research Institute Senior Research Fellow, Center for Water and the Environment	Avian ecology, forest management
Jerry Belant, PhD candidate	NPS-Pictured Rocks National Lakeshore Center Director, Pictured Rocks Science Center and Terrestrial Ecologist	Wildlife ecology
Noel Pavlovic, Ph.D.	USGS- Great Lakes Science Center, Lake Michigan Ecological Station Ecologist	Oak Savanna/woodland/forest ecology, invasive species, rare plant demography, community ecology, statistical analysis
Walter Loope, Ph.D.	USGS-Great Lakes Science Center, Munising Biological Station Ecologist	Physiographic ecology, disturbance ecology, historical ecology
Tom Rooney, Ph.D.	University of Wisconsin-Madison Assistant Scientist, Department of Botany	Population and community ecology, forest plant communties
John Gross, Ph.D.	NPS-Intermountain Region Ecologist	Ecosystem ecology, quantitative ecology, resource monitoring
Jim Meeker, Ph.D.	Northland College Associate Professor of Biology and Natural Resources	Wetland ecology
Phyllis Adams, Ph.D.	NPS-Midwest Region Regional Inventory and Monitoring Coordinator	Forest monitoring
George Host, Ph.D.	University of Minnesota-Duluth Natural Resource Research Institute Senior Research Associate, Center for Water and the Environment and Director, GIS Laboratory	Wetland ecology

APPENDIX C

Priority monitoring issues and questions from scoping workshops held at nine National Park Service units in the Great Lakes Inventory and Monitoring Network. The workshops were held in 2002 to help define Vital Signs for long-term ecological monitoring.

Results of park scoping sessions				Vital Sign(s) associated with park issues and questions[3]
Monitoring issue	Monitoring questions/issues	Park[1]	Votes[2]	
Sand dune and shoreline change	What are the natural and human induced changes in dune and shoreline dynamics?	SLBE	3	Aeolian, lacustrine geomorphology
Sandscapes	How is visitor use impacting sandscape ecosystems? How is sandscape geomorphology changing?	APIS	2	Aeolian, lacustrine geomorphology
Island erosion and disappearance	Are islands expanding or shrinking?	MISS	1	Aeolian, lacustrine geomorphology
Landscape dynamics	What are the trends in geomorphic processes such as bluff erosion, sandscape changes, wetland change, hill slope change, and drainage patterns?	APIS	0	Aeolian, lacustrine geomorphology
Coastal Processes	Is natural erosion threatening cultural resources? How are coastal areas changing? How are human structures impacting coastal processes?	APIS	0	Aeolian, lacustrine geomorphology
Shoreline physical change	How does the shoreline change with time, lake levels, climate change etc.?	PIRO	0	Aeolian, lacustrine geomorphology; Water level fluctuations
Air quality	How is the quality of the air linked to ecosystem quality? What are the trends? How does it affect rare vegetation?	INDU	3	Air contaminants
Air	How does deposition change through time? How does it affect aquatic and terrestrial systems?	ISRO	1	Air contaminants
Pollution / air and water quality	Are pollutants at levels that have negative affects on human health or the environment?	INDU	1	Air contaminants
Air quality	What are the changes in air quality through time and how does it fit with other network parks?	SLBE	0	Air contaminants
Contaminants	Are contaminants effecting the ecosystem and organisms? What are the trends in contaminants?	APIS	0	Air contaminants; Toxic concentrations in water

Appendix C. continued

Results of park scoping sessions				Vital Sign(s) associated with park issues and questions[3]
Monitoring issue	Monitoring questions/issues	Park[1]	Votes[2]	
Mercury / aquatic contaminants	What are the impacts of mercury and other contaminants on the ecosystem?	VOYA	3	Air contaminants; Toxic concentrations in water; Trophic bioaccumulation; Advanced water quality suite
Pollutants in general (air, water etc.	How have humans contaminated the ecosystem?	VOYA	1	Air contaminants; Toxic concentrations in water; Trophic bioaccumulation; Advanced water quality suite
Environmental contaminants	What are the trends in some of the more pervasive and toxic contaminants?	PIRO	1	Air contaminants; Toxic concentrations in water; Trophic bioaccumulation; Advanced water quality suite
Air quality related values	What are air quality trends and status? What are the impacts of air quality on other ecosystem components and processes? What is the significance of airborne contaminants? Light pollution impacts? Noise and soundscapes?	APIS	1	Air quality related values (AQRV)
Turtles	What are the trends in abundance? What is the recruitment rate? How are nesting sites being affected over time?	MISS	3	Amphibians & reptiles (herptiles)
Amphibians and reptiles	What are the population trends? How did they get to the Islands? What percentage have deformities? What do they tell us about the status of the ecosystems? How do they correlate to climate? Which species should be present but are not?	APIS	2	Amphibians & reptiles (herptiles)
Turtles and frogs	How well are we protecting turtle nesting areas? What are the trends in sensitive species?	SACN	1	Amphibians & reptiles (herptiles)
Herp abundance and health	What are the trends in amphibians and reptiles - are they indicators of impacts?	PIRO	1	Amphibians & reptiles (herptiles)
Frog and toad surveys	How are the population changing and are management actions, or lack of, working?	MISS	0	Amphibians & reptiles (herptiles)

APPENDIX C. CONTINUED

Results of park scoping sessions				Vital Sign(s) associated with park issues and questions[3]
Monitoring issue	Monitoring questions/issues	Park[1]	Votes[2]	
Perturbations	How are aquatic pathogens affecting park resources?	GRPO	1	Aquatic pathogens; Terrestrial pests, pathogens
Wetlands	Are wetlands continuing to function and provide ecological services? They are sensitive to change.	VOYA	1	Aquatic/wetland plant communities
Streams and adjacent wetlands	What are the changes in key indicators of streams and wetlands?	SLBE	1	Aquatic/wetland plant communities
Wetlands	What is the status and integrity of park wetlands?	SLBE	1	Aquatic/wetland plant communities
Aquatic plants	Monitor the vegetations response to providing a more natural flow regime.	MISS	1	Aquatic/wetland plant communities
Wetlands	How are wetlands changing over time (isostatic rebound, invasive species, climate change, lake levels)?	APIS	1	Aquatic/wetland plant communities
Wetland integrity	Is the integrity of wetlands changing?	PIRO	0	Aquatic/wetland plant communities
Wetlands	How are wetlands withstanding visitor use and how well are they functioning?	ISRO	0	Aquatic/wetland plant communities
High quality aquatic habitat	To determine the health of certain biologically diverse aquatic habitats - are they changing?	SACN	1	Aquatic/wetland plant communities; Fish communities; Mussels & snails
Ecosystem Process	What are the important ecological processes and how are they doing? Do ecosystem processes differ on the islands and between islands from mainland communities? How does diversity relate to island biogeography?	APIS	0	Biotic diversity
Birds and waterfowl	Is the corridor meeting their needs for migration and resident use and how is it changing over time? Nesting success rates? How is species composition changing through time?	MISS	4	Bird communities
Bird Monitoring	What are the trends in bird populations (compared to other areas)? Are birds good indicators of ecosystem health? How do the Apostles function as a migratory corridor?	APIS	3	Bird communities
Song birds	What are the changes in songbird populations as an indicator of habitat changes in and outside of park?	SLBE	1	Bird communities

APPENDIX C. CONTINUED

Results of park scoping sessions				Vital Sign(s) associated with park issues and questions[3]
Monitoring issue	Monitoring questions/issues	Park[1]	Votes[2]	
Breeding birds	What are the population trends (species distribution, reproductive success), especially those that are sensitive to habitat fragmentation?	SACN	1	Bird communities
Breeding bird survey	How does the bird community change through time and in relation to disturbance, weather, etc.?	PIRO	1	Bird communities
Breeding birds	Is this a sink or source population? And are management actions (restoration) effective?	MISS	1	Bird communities
Birds	What is the status of bird pop'ns as an indicator of the health of park habitats?	INDU	1	Bird communities
Water quality	How does water quality affect restoration processes? Need to improve the time lag of ecoli test results. How do the trends in water quality correlate to the ecosystem health? What are the impacts of the streams and ditches on human health?	INDU	7	Core water quality suite; Advanced water quality suite; Aquatic pathogens
Water quality	How do VOYA waters stack up to the state criteria for outstanding waters and overall biotic integrity?	VOYA	5	Core water quality suite; Advanced water quality suite; Aquatic pathogens
Water quality (aquatic integrity)	What human influences/exotic species are changing the overall aquatic integrity? Ha: Aquatic aliens are increasing in all systems and compromising integrity? (add freshwater sponges to this list) What are changes in community composition?	SLBE	5	Core water quality suite; Advanced water quality suite; Aquatic pathogens
Aquatic integrity	Assessing the trend in overall aquatic health. What are the impacts from tributaries?	SACN	5	Core water quality suite; Advanced water quality suite; Aquatic pathogens
Water quality	What are the trends and status of water quality spanning the river, especially above and below sources of pollution and tributaries?	SACN	4	Core water quality suite; Advanced water quality suite; Aquatic pathogens
Aquatic integrity index	How does it change with land use practices and pollution events?	PIRO	3	Core water quality suite; Advanced water quality suite; Aquatic pathogens

APPENDIX C. CONTINUED

Results of park scoping sessions				Vital Sign(s) associated with park issues and questions[3]
Monitoring issue	Monitoring questions/issues	Park[1]	Votes[2]	
Aquatic biologic (ecosystem) integrity	What are the long term changes and effects in the aquatic environment related to human activities?	VOYA	2	Core water quality suite; Advanced water quality suite; Aquatic pathogens; Land use / land cover fine scale
Aquatic integrity	How does aquatic integrity change through time?	ISRO	4	Core water quality suite; Advanced water quality suite; Fish communities
Water quality (aquatic integrity)	What are the trends in aquatic ecosystem health? Consider issues that the Monument has some control over, but recognize big picture.	GRPO	3	Core water quality suite; Advanced water quality suite; Fish communities
Aquatic integrity	Water quality status and trends? Aquatic organisms and fish populations status and trends? Native and Exotic invertebrate? Effects of contaminants on aquatic communities?	APIS	3	Core water quality suite; Advanced water quality suite; fish communities
Water quality	How is the water quality and how does it vary within the corridor and over time? And where are there hot spots of toxics etc (for example storm water run off)? How does it effect mussel populations?	MISS	4	Core water quality suite; Advanced water quality suite; Mussels & snails
Water temps, physical characteristics	How does water temperature and lake levels affect exotics and sensitive species.	ISRO	1	Core water quality suite; Water level fluctuations; Plant and animal exotics
Fish	What are trends in fish harvest and populations of critical species? Should we still harvest? For ex. lake perch are harvested and seem to have declined.	ISRO	4	Fish communities
Unique fish communities	Is species richness and composition changing within restoration areas?	MISS	1	Fish communities
Stream flow	What are the long term trends in flow - continuous system (instantaneous). Are critical habitats covered by water? Is the river floatable today?	SACN	1	Fluvial geomorphology
Commercial navigation	What are the impacts to the resource?	MISS	1	Fluvial geomorphology

APPENDIX C. CONTINUED

Results of park scoping sessions				Vital Sign(s) associated with park issues and questions[3]
Monitoring issue	Monitoring questions/issues	Park[1]	Votes[2]	
LTRMP	How is the geomorphology of the river changing in response to human impacts? (possibly bring the LTRMP program to pool 2)	MISS	2	Fluvial geomorphology; Land use / land cover fine scale
Harvested species (fish & wildlife	What are the effects of harvest in and around the park?	VOYA	2	Harevested species
Resource extraction	What are the trends in harvest of wildlife, fish, and timber?	PIRO	2	Harevested species
Harvested species (game birds, ethnobotanics, fish and animals)	What are the trends in harvest? Do traditional harvest equations work on the islands?	APIS	0	Harevested species
IBI	How is the aquatic integrity?	MISS	0	IBI
Recreation use	What are the impacts to the resource (I.e. shoreline and nearshore habitat)? Include the behavior of various species like eagles, otters, fish, mink	MISS	3	Land use / land cover fine scale
Restoration	Are restoration efforts effective?	MISS	3	Land use / land cover fine scale
Restoration	Measuring success in achieving restoration goals.	INDU	2	Land use / land cover fine scale
Recreation	What are the trends in impacts of recreational activities?	GRPO	2	Land use / land cover fine scale
Human use and impacts	What are the trends in human use and the associated impacts?	GRPO	2	Land use / land cover fine scale
Park management	How does park operations affect critical resources?	ISRO	1	Land use / land cover fine scale
Visitor enjoyment	These are issues that if monitored would effect visitors to a great extent.	INDU	1	Land use / land cover fine scale
Unintentional human impacts	What are the trends in impacts of these human activities?	GRPO	1	Land use / land cover fine scale
Recreation/ Human impacts	How are visitors/ facilities impacting the parks natural resources? What is the effect of dispersed camping on park resources? How can we manage resources to accommodate expected increases in use?	APIS	1	Land use / land cover fine scale

APPENDIX C. CONTINUED

Results of park scoping sessions				Vital Sign(s) associated with park issues and questions[3]
Monitoring issue	Monitoring questions/issues	Park[1]	Votes[2]	
Land cover	What is the change in land cover over time? Especially wildlife habitats and corridors and high quality vegetation (habitat) areas (examine size and shape). Are land restoration efforts having a positive impact?	MISS	7	Land use / land cover fine scale; Land use / land cover coarse scale
Landscape monitoring	What changes are taking place on the landscape level and how does it impact the Riverway? To examine the continued growth in human population and use. Special attention to wetland, and riparian buffers, corridors, fragmentation.	SACN	6	Land use / land cover fine scale; Land use / land cover coarse scale
Land use change	How does VOYA fit in the regional land use context? What is the regional significance of VOYA? What are the long-term effects on the park ecosystem and visitor experience? How are landscape functions such as wildlife corridors effected by land use change?	VOYA	4	Land use / land cover fine scale; Land use / land cover coarse scale
Land use change	What are the trends in land use in and around the park - including logging, cabin and home building, roads, etc.?	PIRO	4	Land use / land cover fine scale; Land use / land cover coarse scale
Landscape use change	How are human induced impacts related to geoindicators? How do land use practices affect natural resources?	SLBE	3	Land use / land cover fine scale; Land use / land cover coarse scale
Breakdown of natural landscape pattern	What are the changes in wildlife corridors and forest fragmentation changing?	SLBE	3	Land use / land cover fine scale; Land use / land cover coarse scale
Land use change	How is land use changing (rate) and how do we structure management prescriptions for a changing urban area? How is ownership changing over time?	MISS	3	Land use / land cover fine scale; Land use / land cover coarse scale
Campsite monitoring	What is the level of human use and associated impacts?	SACN	2	Land use / land cover fine scale; Land use / land cover coarse scale
Ecosystem health	What are the trends in key ecosystem components (I.e. fragmentation, invasive species, pest species,)	INDU	2	Land use / land cover fine scale; Land use / land cover coarse scale
Land use change	How has habitat fragmentation affected habitat partitioning for available resources and normal range of behavior?	INDU	2	Land use / land cover fine scale; Land use / land cover coarse scale

APPENDIX C. CONTINUED

Results of park scoping sessions				Vital Sign(s) associated with park issues and questions[3]
Monitoring issue	Monitoring questions/issues	Park[1]	Votes[2]	
Land use and environmental	What are the trends in changing environment and land use? Land use and changes including logging, building of homes and cabins, etc. What are the trends in fragmentation, connectivity, etc?	GRPO	2	Land use / land cover fine scale; Land use / land cover coarse scale
Human distribution and abundance (migration)	How are human use patterns changing?	PIRO	0	Land use / land cover fine scale; Land use / land cover coarse scale
Deer surveys and corridors	Are habitat fragments available to wildlife?	MISS	1	Land use / land cover fine scale; Land use / land cover coarse scale; Problem species
Wolf/moose	What are the trends in the top predator/prey system and how does it affect other resources (forest change)?	ISRO	2	Mammal communities
Mammals	Identify 1-5 "miners canaries" for systems change.	ISRO	1	Mammal communities
Mammals	What are the population trends? What are the impacts on vegetation? What are the population sizes of species that are important to the public?	APIS	0	Mammal communities
Freshwater mussels	To determine the trends in the existing populations of both native and exotics. To assess management actions. Is recruitment adequate, what is species richness and abundance? Are we managing for the host fish?	SACN	7	Mussels & snails
Native and exotic mussel populations	What are the trends in native mussels and is there a zebra mussel threat? Higgin's eye mussels should be a primary concern. Are the host fish spp present in needed abundance? Look at changes in species richness, distributions, population demographics, especially reintroduced species.	MISS	6	Mussels & snails
Invasive species	What are the patterns and trends of exotics and invasives in the park? Assess current management programs.	INDU	7	Plant and animal exotics

APPENDIX C. CONTINUED

Results of park scoping sessions				Vital Sign(s) associated with park issues and questions[3]
Monitoring issue	Monitoring questions/issues	Park[1]	Votes[2]	
Exotics	What are the trends in exotics and how do they affect other ecosystem components (what is exotic?). Must help safeguard natural environments and prevent further invasions. Is it correlated with human use?	ISRO	6	Plant and animal exotics
Exotics both terrestrial and water	What is the changing distribution of exotics and how do they effect other resources?	VOYA	4	Plant and animal exotics
Invasive species	What areas are being invaded by new non-native species? How is ecological integrity changing due to invasive species? How do we prevent other lakes from being infected?	SLBE	3	Plant and animal exotics
Exotic plants	Are management actions effective? To help prioritize for management actions. What species are out there, what is the distribution and rates of decline?	SACN	3	Plant and animal exotics
Invasive species	What is the distribution and abundance? What is the rate of advance?	PIRO	3	Plant and animal exotics
Invasive plant species	Are our efforts effective (use to prioritize efforts)? Is the distribution and abundance responding to management and education?	MISS	3	Plant and animal exotics
Invasive spp	Is management effective at reducing the distribution and abundance of invasives? Methods that will identify new invasives.	MISS	2	Plant and animal exotics
Invasive terrestrial plants	How do invasive spp adversely affect restoration projects?	MISS	2	Plant and animal exotics
Invasive and nuisance species	What are the trends in distributions and abundance and associated impacts? Early warning of invasion and evaluation of management activities.	GRPO	2	Plant and animal exotics
Exotics	How are exotics impacting native resources? Are they spreading? Do they have a disproportionate effect on the islands?	APIS	2	Plant and animal exotics
Aquatic exotics	Extent and impact of aquatic invasive, both plant and animal.	VOYA	1	Plant and animal exotics

APPENDIX C. CONTINUED

Results of park scoping sessions				Vital Sign(s) associated with park issues and questions[3]
Monitoring issue	Monitoring questions/issues	Park[1]	Votes[2]	
Deer monitoring	What are the trends in deer numbers? What are the effects of deer on park resources?	INDU	2	Problem species; Terrestrial plants
Human visual and auditory impacts	What are the levels and trends in human-caused noise and observable objects (i.e. boats, tents, etc)?	VOYA	0	Soundscapes, light pollution
Index to naturalness	How do humans w/in and outside of the park affect the natural character of the park and across the network?	ISRO	0	Soundscapes, light pollution
Rare plants	What is the stability of rare plant populations, what factors effect them, long-term trends?	INDU	6	T&E species
Animals of special concern	Status and trends of important vertebrates and invertebrate? To include areas with extirpated pop'ns of Karner Blue butterflies .	INDU	6	T&E species
Key indicator species	What are the trends in T&E and other key species in relation to habitat?	SLBE	4	T&E species
Special wildlife	What are the trends in selected species of concern (including insects, moose?	GRPO	2	T&E species
Rare and sensitive species	What is the status of rare and sensitive species? Are distributions changing and what role does the park play in protecting those species.	VOYA	1	T&E species
T&E species	What are the populations levels and range size of critical T&E species?	PIRO	1	T&E species
Management priorities (legal mandates…	How are priority natural resources changing over time? Are we meeting our management goals?	MISS	1	T&E species
Rare plants	How are rare plants affected by climate, human impacts, development, etc.?	ISRO	1	T&E species
Karner Blue	Are we doing the right thing in managing for Karner blue butterflies?	INDU	1	T&E species
Rare species	How are demographics of rare species changing? Potential for use as bioindicators.	MISS	0	T&E species

APPENDIX C. CONTINUED

Results of park scoping sessions				Vital Sign(s) associated with park issues and questions[3]
Monitoring issue	Monitoring questions/issues	Park[1]	Votes[2]	
Threatened and Endangered Species (rare)	What are the trends and status of T and E species?	APIS	0	T&E species
Species of concern	What are the trends in key plant and animal species including exotic and natural species?	INDU	3	T&E species; Plant and animal exotics
Management actions	How effective is the management actions in promoting ecosystem health? Include Karner blue butterflies and fire program.	INDU	2	T&E species; Plant and animal exotics
Dragonfly monitoring	How are the populations changing in abundance and distribution? How does it reflect the aquatic environment?	SACN		Terrestrial invert communities
Insects	Which insects are important environmental indicators (Lepidoptera)? What is the status of insects that have human health concerns? What are the potential impacts of gypsy moths and other pests?	APIS	0	Terrestrial invert communities; Terrestrial pests, pathogens
Insect and arachnids	What is the likelihood of disease transmission to humans? What are the trends in infection?	INDU	1	Terrestrial pests, pathogens
Terrestrial integrity (quality)	How is the terrestrial integrity being compromised due to overall change? (FHM as a potential tool) What are the changes in community composition?	SLBE	3	Terrestrial plants
Terrestrial integrity [all terrestrial]	Assessing the trend in overall terrestrial health. What are the trends and changes?	SACN	3	Terrestrial plants
Forest health	How does forest change affect other species? How does it indicate change? How does ISRO vegetation health compare regionally?	ISRO	3	Terrestrial plants
Terrestrial biologic integrity	What are the long term changes and effects in the terrestrial environment related to human activities?	VOYA	2	Terrestrial plants
Vegetation community (FHM)	How is the vegetation community changing including disease, species composition, dead and down wood etc?	PIRO	2	Terrestrial plants
Vegetation management	Are the current conditions w/in the targeted range defined by management plans?	INDU	1	Terrestrial plants

Results of park scoping sessions				Vital Sign(s) associated with park issues and questions[3]
Monitoring issue	Monitoring questions/issues	Park[1]	Votes[2]	
Vegetation	What are the trends in vegetation and habitat?	GRPO	1	Terrestrial plants
Community level vegetation monitoring	What is the status and health of rare vegetation communities? Include all communities. What damages are present? FHM-type monitoring.	SACN	1	Terrestrial plants; Aquatic/wetland plant communities
Habitat	What are the trends in aquatic and terrestrial habitats?	GRPO	1	Terrestrial plants; Aquatic/wetland plant communities
Landscape/vegetation changes	How are vegetation communities changing over time. What is the disturbance regime for different ecosystem types? How do landscapes recover from disturbance? What is the impact of natural on cultural and vica versa? What are the impacts of plant harvest (including by Native Americans)?	APIS	5	Terrestrial plants; Land use / land cover coarse scale
Long term forest change	What is the sustainability of forest communities given lack of fire and potential changes in insect invasions, blow downs, and climate change?	VOYA	4	Terrestrial plants; Land use / land cover coarse scale
General vegetation	Are protocols used to monitor small "natural areas" effective at measuring goals? Are the vegetation communities supporting rare plants?	MISS	3	Terrestrial plants; Land use / land cover fine scale
Forest Ecosystem	How are forest ecosystems changing with time? How do they differ based on past disturbances? Is there a way to measure their resiliency?	APIS	3	Terrestrial plants; Land use / land cover fine scale
Terrestrial integrity index (cumulative impacts)	Need a multi-metric index to monitor cumulative impacts of humans on park terrestrial resources.	PIRO	1	Terrestrial plants; Land use / land cover fine scale
Forest integrity	Monitor for decline in these key species. What is the change in forest composition, disease in beech, through time?	SLBE	2	Terrestrial plants; Terrestrial pests, pathogens
Aquatic pollutants	How do pollutants impact the resources? What contaminants pose the greatest threats?	ISRO	2	Toxic concentrations in water
Water flow	What is the daily, monthly, seasonal, and annual changes (peal events also)?	MISS	0	Water level fluctuations; Advanced water quality suite

APPENDIX C. CONTINUED

Results of park scoping sessions				Vital Sign(s) associated with park issues and questions[3]
Monitoring issue	Monitoring questions/issues	Park[1]	Votes[2]	
Lake levels	What affect did the 2000 rule curve have on key indicators such as loons, wetland plants.	VOYA	4	Water levels
Phenology/Climate	What are the differences in phenology across the network through time, and from island to island? What Max min weather and other parametric data (context for other analysis)?	APIS	2	Weather, meteorological data
Climate change	How does climate change affect plant distribution and other resources. Blow downs and other storm events may increase.	VOYA	1	Weather, meteorological data
Climate and atmospheric change	What are the weather patterns and how are they changing? How does weather affect other resources (winter severity index)?	PIRO	1	Weather, meteorological data
Weather	How do weather trends effect hydrology and soil composition? What selective effects does this have on flora and fauna?	INDU	1	Weather, meteorological data
Climate	How does climate characterize and affect change in park ecosystems?	SLBE		Weather, meteorological data
Processes	Monitor key drivers of the system - how does it change through time? What is the range of natural variability? How do weather patterns affect nutrient cycles?	ISRO	4	Weather, meteorological data; Nutrient dynamics, biogeochemistry;

1= Parks: APIS=Apostle Islands National Lakeshore, GRPO=Grand Portage National Monument, INDU=Indiana Dunes National Lakeshore, ISRO=Isle Royale National Park, MISS=Mississippi National River and Recreation Area, PIRO=Pictured Rocks National Lakeshore, SACN=St. Croix National Scenic Riverway, SLBE=Sleeping Bear Dunes National Lakeshore, VOYA=Voyageurs National Park.

2= Votes are the number of natural resource staff in the park who identified the issue in the top 5 need for monitoring data. Number participating are as follows: APIS=5, GRPO=3, INDU=10, ISRO=6, MISS=12, PIRO=4, SACN=9, SLBE=6, SACN=9, VOYA=7.

3= Vital Signs are indicators of park ecosystem change which will help parks understand their resource, anticipate change, and manage in a scientifically defensible manor.

APPENDIX D

INFORMATION FOR PARK RESCORING OF VITAL SIGNS

Information provided to park staff for rescoring Vital Signs during the second round of the selection and prioritization process on 3/1/2004. The information briefly summarizes discussions and scoring by scientists who participated in advisory and focus groups and information from conceptual models.

Aq # = Average score from the aquatic and air resources workshop

Terr # = Average score from the terrestrial and wetlands workshop

Pk # = Average score from representatives of the nine parks

Blanks appear where scoring was not applicable for a particular group

WATER QUALITY

#1 Core water quality suite - *Measures* mandated by the Water Resources Division are temperature, conductivity, pH, dissolved oxygen, and some measure of stream flow or lake level.

Ecological significance (Aq 4.5, Terr 4.6, Pk 3.9) Both focus workshops noted the high significance of this indicator as it integrates with other data on water quality. Water levels and flow are particularly important and are covered in greater detail in indicator #14.

Management significance (Pk 3.6) Some parks designated as Outstanding Resource Waters. In enabling legislation for some parks (i.e. SLBE). Certain measures are problems for specific parks and reasons for them being listed with impaired waters under 303(d) of the Clean Water Act.

Measurability/Sensitivity (Aq 4.7, Terr 4.4) While there was no discussion about the sensitivity of the parameters to change, the groups noted that all 5 variables are relatively easy to measure. Because there will be tremendous variability both spatially and temporally, there was a lot of discussion about the frequency and cost of meaningful sampling.

#2 Advanced water quality suite - *Measures* include chlorophyll a, organic carbon, major ions, nutrients, turbidity, suspended sediments, light penetration.

Ecological significance (Aq 4.7, Terr 3.6, Pk 4.1) Significance is critical, as these parameters characterize the medium for all aquatic organisms.

Management significance (Pk 3.7) Concerns regarding influx of nutrients and sediments from runoff and tributaries.

Measurability/Sensitivity (Aq 4.2, Terr 2.8) Some of these parameters will be expensive to monitor, but standard methods exist. Ion chemistry varies little, so it would not need to be measured as often as some other parameters. Chlorophyll a is not as sensitive as expected, according to studies in Canada, but many folks still use it. Some of the parameters are sensitive to watershed disturbances.

#3 Aquatic pathogens - *Measures* include *E. coli*, fecal coliform, and cyanobacteria counts; other species may be important in the future.

Ecological significance (Aq 1.9, Terr __Pk__) These pathogens are related more to human use than to ecosystem function. The effects are often very localized.

Management significance (Pk__) This can be a significant human health risk causing beach closures in some Network parks (INDU, SLBE). Lakeshore samples are needed for community relations. Means of anticipating pulses would be desirable.

Measurability/Sensitivity (Aq 2.9, Terr__) Sampling should be conducted in areas of human use after runoff events. The measures may indicate overall land use and can be linked to the land use/land cover indicators (#12 & 13).

#4 Sediment analysis - *Measures* include nutrients, diatoms, pollen, texture (sand, silt, clay), embeddedness.

Ecological significance (Aq 4.5, Terr __, Pk 3.3) Sediments are integrative, give a picture of processes (sediment/water column exchange), and can be used for historical context.

Management significance (Pk 2.6) Dredging impacts sediment deposits on beaches and may contribute to the release of contaminants. Some species (e.g., mussels and fish) are impacted by sedimentation. See indicator #16.

Measurability/Sensitivity (Aq 3.8, Terr__) Biogenic silica is probably the best measure of overall productivity; it is measurable and sensitive to annual change.

CONTAMINANTS

#5 Trophic bioaccumulation - *Measures* could include contaminant loads in various organisms (e.g., fish, bald eagle chicks, otter, mink, snapping turtle eggs, loons, colonial waterbirds). Stable isotopes may be used to trace the origin of a contaminant.

Ecological significance (Aq 4.4, Terr 3.3, Pk 3.6) Bioaccumulation of toxics is known to impair wildlife at upper trophic levels (egg shell thinning). Fish may be the first organisms to show bioaccumulation of toxics, and lots of other organisms eat fish, hence bioaccumulation in fish has impacts across trophic levels.

Management significance (Pk 3.1) Bioaccumulation is a threat to upper trophic levels, including species of concern and humans. Fish consumption advisories reflect these health concerns and impact park visitors.

Measurability/Sensitivity (Aq 3.7, Terr 2.4) It is best to sample an organism at an intermediate trophic position (fish). Standard methods exist for measuring bioaccumulation, but such measures are expensive. Other agencies are currently monitoring this indicator so data are available.

#6 Health, growth, and reproductive success - *Measures* include percentages of organisms with tumors or percent reproductive success of organisms listed in #5.

Ecological significance (Aq 3.7, Terr 2.7, Pk 3.0) Neither Focus Group had specific comments on the ecological significance, but there are obvious species-specific implications and it could uncover systemic problems.

Management significance (Pk 2.8) May reflect wildlife and human health concerns. Tumors on fish are a management concern on the Great Lakes.

Measurability/Sensitivity (Aq 1.8, Terr 2.9) Recording incidence of lesions, tumors, or deformities can be accomplished along with other organism/community monitoring. Cause and effect would be difficult to discern.

APPENDIX D

#7 Air deposition/contaminants (changed from air quality) - *Measures* would consist of a variety of contaminants and nutrients deposited atmospherically (N, NO3, NH4, pesticides, P, Hg, S, atrazine, brominated compounds), as well as ozone.

Ecological significance *(Aq 4.0, Terr 4.1, Pk 3.0)* Significant in both aquatic and terrestrial systems. SO4 influences methylation of Hg; high N leads to declines in fungal communities; succession, susceptibility to disease, tree growth are all affected by deposition; chemical composition of leaves can change, which may lead to changes in the taste of caterpillars and avoidance by birds (hence cascading trophic effects).

Management significance *(Pk 2.1)* Ozone, mercury, and other toxics are of concern depending on the park.

Measurability/Sensitivity *(Aq 2.5, Terr 3.4)* Requires a reactive monitoring program, as it's very difficult to anticipate which of many new toxics to measure next. Monitoring is being conducted by others (e.g., NADP), so data are available.

#8 Toxic concentrations in water - *Measures* include contaminant concentrations in wastewater and surface water.

Ecological significance *(Aq 2.6, Terr__, Pk 3.0)* Toxic chemicals in water bioaccumulate in species at upper trophic levels and can impact wildlife health and reproductive success. Linked to other indicators (#6, #7, #9).

Management significance *(Pk 3.2)* Toxic concentrations in stream systems can help locate point source discharges. Private and municipal sewage disposal and boathouses are sources of concern.

Measurability/Sensitivity *(Aq 2.1, Terr __)* It is important to measure the co-factors of pH, organic C, and major ions when measuring any contaminant in water. Often contaminants are dilute in water and therefore difficult to measure. It is often better to look at organisims that bioaccumulate the toxics. This may be more of a research question, such as assessing the direct toxicity to aquatic organisms, rather than part of a monitoring program. There are high lab costs involved and lots of variability over time.

#9 Toxic concentrations in sediments (added at Air/Aquatic Worshop) - *Measures* would be the contaminant loads in sediments and interstitial porewater.

Ecological significance *(Aq 3.8, Terr__Pk__)* More significant than concentrations in water. Sediments are a reservoir for many toxics.

Management significance *(Pk__)*. Disruption of sediments can release toxics into the food web and is related to dredging and other management activities. See also indicators #4 and #8.

Measurability/Sensitivity *(Aq 3.2, Terr__Pk__)* Again, it is important to measure the co-factors of major ions, organic C, and pH. Concentrations in sediments are useful for tracking changes of inputs over time, but not for assessing direct toxic exposure.

LANDSCAPE, LAND USE CHANGE

#10 Air quality-related values (AQRVs) - *Measures* include particulates, visibility, smell and resources impacted by air quality (e.g., Ozone effects on vegetation).

Ecological significance *(Aq 1.6, Terr 1.9, Pk 3.2)* Directly affects plant and animal health including humans.

Management significance (Pk 3.1) There are mandates for class I and II airsheds. Smells and viewsheds in relation to visitor experience are issues in some parks.

Measurability/Sensitivity (Aq 2.6, Terr 2.9) Standard protocols exist (e.g., viewshed cameras, ambient monitors, plot sampling of plants). The cost is variable, but can be high, and monitoring is time consuming. Previous use of lichens may be questionable, but can be supportive of ambient monitoring.

#11 Soundscapes and light pollution (separated from AQRV at Air/Aquatic Workshop) - *Measures* include recording decibels and lumens (night skies).

Ecological significance (Aq 3.3, Terr 1.4, Pk__) Many animals depend on sound to distinguish between species, individuals, and mates, and to detect prey. There is evidence that unnatural sound and light may alter wildlife and insect movements, mating systems, and other behaviors. Photoperiod and light intensity can be important signals for physiological and behavioral changes.

Management significance (Pk__) Noise from vehicles, boats, snowmobiles, and ATVs may affect wildlife. Light can disrupt migration patterns of birds.

Measurability/Sensitivity (Aq 3.0, Terr 1.6) Remote sensing is possible thus reducing cost, but the science is not well developed and statistical properties of metrics are not well understood. Some data exist, but quality varies. Baseline data may be more important than developing a periodic monitoring program at this point.

#12 Land cover/land use coarse scale (land cover and land use combined at Air/Aquatic Workshop) (~30 meter resolution imagery) **-** *Measures* include cover type, patch size, fragmentation, edge, slope, aspect, connectivity of land/water types, human density, current & past human use (agriculture/forestry), and large-scale disturbances (fire, wind throw).

Ecological significance (Aq 4.4, Terr 4.9, Pk 3.6) Critical for assessing change in terrestrial and aquatic systems. It integrates well with other indicators and with data available from partners (EPA point/source data, SOLEC, etc).

Management significance (Pk 3.4, avg of land cover coarse scale and land use coarse scale scores) This indicator can help put parks into context. Development and urban sprawl impact parks. Measures can answer important questions such as how connectivity to adjacent habitat alters movements of native and exotic organisms.

Measurability/Sensitivity (Aq 4.3, Terr 4.0) Standard metrics exist. Road density, habitat fragmentation, and human density are examples of metrics that are sensitive to changes in some wildlife use patterns. Terrestrial group suggests limiting to four or five parameters that capture a majority of issues. There are statistical concerns about some metrics (e.g., mean patch size). The national I&M program, including a GLKN contractor (U of MN), is developing a “white paper” on this indicator.

#13 Land cover/land use fine scale (land cover and land use combined at Air/Aquatic Workshop) (~1 meter resolution imagery) **-** *Measures* would be of higher resolution and finer detail compared to the coarse scale indicator. This could include percent hardened shoreline, number of artificial structures, area (m^2) of various habitats, density of campsites, trails, roads, other facilities.

Ecological significance (Aq 3.5, Terr 4.4, Pk 3.2) Cumulative fine scale impacts may have significant impacts on watershed dynamics. The fine scale is important for understanding migration/invasion of exotics, influences of structures (breakwaters), and human use. This indicator integrates well with other indicators (#16, #25, #42, #45, and #46).

<u>Management significance</u> *(Pk 3.6, avg of land cover fine scale and land use fine scale scores)* This indicator could provide data on many specific management concerns such as density and cumulative impacts from trails, campsites, canoe landings, boat launches, etc., and how they relate both spatially and temporally to resources such as nesting sites, den areas, etc.

<u>Measurability/Sensitivity</u> *(Aq 3.1, Terr 3.2)* Typically done less frequently than coarse scale, normally involves fieldwork and/or ground-truthing, more labor intensive, and thus more costly. Low flight aerial photography is a cost effective method of capturing fine-scale patterns and structures.

ECOSYSTEM PROCESSES

#14 Water level fluctuations - *Measures* include lake levels, stream flow and stage. Should use a benchmark and consider relative vs absolute elevation for lakes.

<u>Ecological significance</u> *(Aq 4.7, Terr 4.2, Pk 3.6)* Highly significant for both rivers and lakes. Tributaries contribute nutrients and sediments cumulatively to the main stem of rivers and knowing their contribution is important. During extreme droughts, die offs of benthic inverts and submersed vegetation occurs. Floods appear to enhance fish productivity.

<u>Management significance</u> *(Pk 2.9)* Stream flow and lake levels affect visitor use as well as fish, wildlife, and nutrient cycling. Several parks have dams that create artificial lake levels and stream flows (it's a dam issue).

<u>Measurability/Sensitivity</u> *(Aq 4.2, Terr 3.6)* Coarse data readily available (Great Lakes, USGS stream gauges), but fine scale data requires gauges and ground-based monitoring. This level of detail is not currently available in most parks. Relatively inexpensive continuous monitoring systems are available; major cost would involve initial site selection and calibration. Formal USGS stream gauge stations can cost $30k to set up and $15k/year for data and upkeep.

#15 Nutrient dynamics/biogeochemistry - *Measures* include land/water decomposition rates, microbial composition, and nitrogen, phosphorus, and carbon levels.

<u>Ecological significance</u> *(Aq 3.6, Terr 3.0, Pk 3.1)* Nutrients are linked to productivity, population dynamics, and forest health. Integrates with work done by others.

<u>Management significance</u> *(Pk 1.8)* Impacts water quality.

<u>Measurability/Sensitivity</u> *(Aq 2.3, Terr 1.7)* Carbon and nitrogen cycling is difficult (costly) to measure. Leaf litter packs (a method of measuring nutrients) are inexpensive, but require extensive repetition in the field and lab. Aquatic group considered this a research question, and noted that decomposition is sensitive to cadmium.

#16 Fluvial (riverine) geomorphology (originally called stream dynamics) - *Measures* for stream systems include rate of scouring, erosion/sedimentation, channel change, development and loss of islands, stream profile, and location of small intermittent streams, wetlands, beaver impoundments, and coarse woody debris.

<u>Ecological significance</u> *(Aq 3.9, Terr 3.4, Pk 2.9)* Critically important to stream biota and riparian habitats.

Management significance *(Pk 2.9)* Can help managers predict changes in stream course and flow and understand the effects on biota. At some parks, flow affects visitor use. Both lack of change (hardening and channelization) and natural change (stream bank erosion) can be issues. Related to indicator numbers #4, #12, #13, and #14.

Measurability/Sensitivity *(Aq 3.5, Terr 3.0)* The use of reference-reaches is easy on small streams, but costly on larger streams. Can be cost effective if aerial photography is used.

#17 Aeolian and lacustrine geomorphology (added at Terrestrial/Wetlands Workshop) - *Measures* relate to the movement of sand by wind, currents, and wave action (change in bluffs, sand spits, dunes, and other beach formations).

Ecological significance (Aq __, Terr 3.6, Pk__) Wind, currents, and waves alter shoreline to a large extent and affect shoreline (riparian) habitat. Can help assess human impacts and is integrative with other indicators of landscape change.

Management significance *(Pk__)* Beaches and bluffs are unique areas that provide habitat to specialized (e.g., Pitcher's thistle) and fugitive species (e.g., sand cherry, beach pea). Technical committee did not score this indicator, but see indicator numbers #12, #13, and #21.

Measurability/Sensitivity *(Aq__Terr 2.8)* Costly since it requires ground-based monitoring or high resolution imagery (LIDAR or aerial photography) but could potentially be captured under land cover/land use fine scale monitoring.

#18 Primary productivity - *Measures* of carbon fixation.

Ecological significance (Aq 4.2, Terr 3.0, Pk 3.4) A significant indicator of the health and function of aquatic systems including wetlands.

Management significance *(Pk 1.3)* Related to nutrient dynamics. See indicator #15.

Measurability/Sensitivity *(Aq 1.4, Terr 2.7)* Primary productivity is costly to measure directly. Better to use indirect measures such as standing biomass, secchi disk readings, diatom community structure, and dissolved oxygen. Data on primary productivity are available from the Forest Service (FIA plots) and Long Term Ecological Research (LTER) sites.

#19 Succession (forests, wetlands) - *Measure* plant growth and replacement following fire, logging, beaver activity, and other disturbances. Use models to predict vegetation trajectory to climax community.

Ecological significance *(Aq 2.4, Terr 3.8, Pk 3. 7)* A fundamental ecological process linked to primary productivity, land cover, and other indicators. This indicator would help evaluate whether vegetation is changing as predicted. Succession of beaver impoundments from forest to pond to sedge meadow has important impacts on hydrology, water quality, and other wildlife species.

Management significance *(Pk 2.9)* Stabilization of dunes, recovery from overuse and anthropogenic changes, and restoration of various habitats (e.g., beaches, oak-savannah, wetlands, and forests) may be issues at parks.

Measurability/Sensitivity *(Aq 1.7, Terr 3.4)* Would require monitoring of associated disturbances to tease out the effects (e.g., exotics and fire suppression). The terrestrial plant communities indicator may help evaluate succession, but to measure it well you would need to design a study for specific disturbances. May be costly and time consuming.

#20 Trophic relations - *Measure* rate of herbivory, predation, population change, and density using species at different trophic levels.

Ecological significance *(Aq 3.1, Terr 3.0, Pk 3.6)* The movement of energy up the trophic scale is a fundamental ecological process. This indicator could evaluate whether systems are out of balance.

Management significance *(Pk 2.6)* Deer and moose browse are of concern. Cyclical nature of prey base in aquatic and terrestrial systems impacts the entire food web. See also indicator numbers #5, #28, and #41.

Measurability/Sensitivity *(Aq 1.1, Terr 3.0)* Herbivory and population change of plants could be easily measured during other vegetation monitoring, but predation rates can be difficult, costly, and time consuming to measure depending on the species.

#21 Geological processes - *Measures* include the number and area (m^2) of major landslides, rock fall, and bluff slumping, and rebound of the Great Lakes.

Ecological significance *(Aq 2.5, Terr 2.9, PK 3.3)* closely related to #16 and #17, but the impact is generally on a larger scale and over a long period of time, though occasionally short term changes occur (e.g., rock fall, landslide).

Management significance *(Pk 3.1)* Areas prone to landslides etc. should be avoided for docks, breakwaters, and harbors. NPS mandates that ecological processes be allowed to continue. See also indicator numbers #12, #13, #16, and #17.

Measurability/Sensitivity *(Aq 2.8, Terr 3.3)*. These types of changes can be measured via remote sensing and through the use of photo points. In general, geologic processes provide background information rather than comprise a component of an ongoing monitoring effort. May be desirable to have a "rapid assessment" program to document large-scale events – both biotic and abiotic.

HABITATS

#22 Land-water transition zone - *Measures* include many parameters that describe the physical and biotic components of selected shoreline. Area of wetland, pebble beach, shrub cover etc., along with plant and animal indices.

Ecological significance *(Aq 4.1, Terr 3.5, Pk 3.6)* The land-water transition zone is a highly productive area that includes both aquatic and terrestrial systems. Related indicator numbers #12, #13, #16, #17, #39, and #46.

Management significance *(Pk 2.3)* These areas are highly visible to the public and are highly used by the public (beaches, boat launches, camping). Vulnerable to oil spills (ISRO) and other disturbances.

Measurability/Sensitivity *(Aq 3.1, Terr 3.0)* Suggest removing as an indicator - more of a sampling design issue; i.e., this is where we measure, rather than what we measure.

#23 Littoral zone (added at the Air/Aquatic Workshop) - *Measures* include the core water quality suite, plankton, aquatic vegetation, and nutrients.

Ecological significance *(Aq 4.4, Terr 3.5, Pk__)* This is a highly productive zone.

Management significance *(Pk__)* Important for fish spawning. See related indicators #22, #28 and #46.

Measurability/Sensitivity (Aq 3.7, Terr 3.5) As above, this is a sampling design issue, not an indicator. All of the measures are indicators.

#24 Soil - *Measures* include moisture, temperature, nutrients, organic matter, duff layer, compaction, degree of rutting.

Ecological significance (Aq 3.6, Terr 3.5, Pk 3.2) Soil is the foundation for all plant communities.

Management significance (Pk 1.8) Soil compaction and erosion are issues at areas of high visitor use. Impacted soils are apt to harbor exotic species. See indicator numbers #19 and #45.

Measurability/Sensitivity (Aq 3.8, Terr 2.4) The aquatics group suggested that soil is a baseline layer that should be part of the land cover/land use category. The terrestrial group suggested that soil measurements be conducted in conjunction with vegetation sampling, and not be monitored alone.

#25 Other special habitats - *Measures* would vary depending on the park. Some examples of special habitats are backwater sloughs, springs, seeps, groundwater discharge areas, dunes, clay banks, wetlands (including ridge swale wetlands), shoreline fens, bogs, and rocky shorelines.

Ecological significance (Aq 3.7, Terr 3.7,Pk 3.9) Biological diversity may be high in these areas or they are the only habitats inhabited by certain species.

Management significance (Pk 3.3) May be very important for some parks. Several of these unique areas may be especially sensitive to visitor use or changes from natural events.

Measurability/Sensitivity (Aq 2.6, Terr 3.3) Specific to the park and type of site. This indicator does not lend itself well to a broad, consistent monitoring program because the types of special habitats, and hence, the measures, protocols, and staff needs would vary widely across parks.

WEATHER AND CLIMATE

#26 Weather, meteorological data - *Measures* include temperature, precipitation, wind, storms, extreme events.

Ecological significance (Aq 4.5, Terr 4.6, Pk 4.0) These are key drivers (identified in all models) and provide context for analyzing changes in other indicators.

Management significance (Pk 2.2) Impacts visitor use and affects all resources.

Measurability/Sensitivity (Aq 4.5, Terr 4.6) Data collection can be automated. We should acquire this information from others who are already collecting it and make it readily available.

#27 Phenology - *Measures* include leaf drop, ice duration, emergence of mayflies and midges, bird arrival, frog calling, date of first killing frost, length of growing season, time of fruiting.

Ecological significance (Aq 3.6, Terr 3.9, Pk 3.6) These measures get at climate change and productivity, linked to #26.

Management significance (Pk 1.7) The impacts of global warming may impact management decisions as habitats are affected. Ice on/ice off and snowfall affects visitor use.

Measurability/Sensitivity (Aq 3.4, Terr 3.6) Some of these may be difficult to measure or interpret. On the other hand, long-term data are collected easily (and by amateurs) and can provide meaningful information. Ice duration datasets are some of the longest running.

APPENDIX D

ORGANISMS, SPECIES, POPULATIONS, COMMUNITIES

#28 Fish communities - *Measures* include species and age composition, catch per unit effort of young of the year (YOY) and adults, recruitment, and stocking rates.

Ecological significance *(Aq 4.5, Terr 3.7, Pk 3.8)* Major part of the food web, important in trophic interactions and transfer of toxics.

Management significance *(Pk 2.8)* Important harvested group in some parks. Stocking of native and non-native species is an issue for some parks. Fish consumption advisories affect visitor use and satisfaction. Refer to indicator numbers #5, #6, #8, and #44.

Measurability/Sensitivity *(Aq 3.7, Terr 3.0)* YOY are highly variable, but long-term data can explain variability. Data may be available from others (e.g., states) for data mining rather than field collection. Select a target group since monitoring the whole fish community would be difficult and expensive.

#29 IBI (Index of Biotic Integrity, reinstituted at the Air/Aquatic Workshop) - *Measures* include relative abundance, species composition (genus in some cases). IBIs can include more than just aquatic macroinvertebrates; for example an IBI can be developed using fish, and has been developed using plants (floristic quality index).

Ecological significance *(Aq 3.4, Terr__Pk__)* The aquatic group agreed that this was generally significant, while the terrestrial group thought IBIs are not very useful and preferred well-developed focus on specific communities.

Management significance *(Pk__)* This indicator was excluded by the technical committee during round 1.

Measurability/Sensitivity *(Aq 2.40, Terr__)* IBIs for streams are generally accepted, but not for lakes or wetlands. Fish IBIs are strongly sample size dependent and require several different methods. Each IBI (regardless of type) is not applicable across a variety of sites, but rather must be developed for each site. IBIs are expensive to develop, requiring a year or more to develop and test for a single stream type.

#30 Aquatic macroinvertebrates (originally benthic invertebrates) - *Measures* include species composition of overall benthic community; density of *Diporeia*, *Hexagenia*, or oligochaetes; EPT ratios (Ephemeroptera Plecoptera, Trichoptera); abundance and species composition of crayfish, sponges, *Mysis*, or odonates.

Ecological significance *(Aq 4.6, Terr 3.7, Pk 3.1)* The importance is often underestimated. The significance is high for secondary production, fish production, and nutrient cycling. See also indicator #42.

Management significance *(Pk 1.6)* Indicator of water quality.

Measurability/Sensitivity *(Aq 3.1, Terr 2.4)* Sampling is labor intensive; taxonomic expertise is required. It would be important to be consistent with state efforts; often associated with IBIs.

#31 Mussels and snails - *Measures* include species composition, density, recruitment, and distribution.

Ecological significance *(Aq 4.3, Terr__, Pk 3.2)* This is a highly threatened group whose sedentary and water siphoning behaviors make them good indicators of habitat and water quality. Often they have complex life cycles, requiring specific host species.

Management significance *(Pk 2.7)* Includes a high number of T&E species (the threat of zebra mussels on native mussels is high). See also indicator #47. This indicator is particularly important for rivers and supportive of indicators #1, #2, and #16.

Measurability/Sensitivity *(Aq 2.8, Terr__)* Methodology exists but sampling is labor intensive and often destructive of substrate. Sampling can be done infrequently (every 5yrs) to mitigate these problems.

#32 Sponges (Air/Aquatic Workshop suggested including sponges and crayfish with macroinvertebrates) - *Measures* are species composition, change in abundance.

Ecological significance *(Aq 2.3, Terr__, Pk 3.0)* Important filter feeders and can grow to large colonies in clean waters.

Management significance *(Pk 2.0)* May inhibit the spread of zebra mussels. Some pristine waters (i.e., ISRO) have large colonies.

Measurability/Sensitivity *(Aq 1.6, Terr__)* Largely unknown. The aquatic group agreed that an inventory would be worthwhile.

#33 Zooplankton - *Measures* include species composition, abundance, and changes in morphology.

Ecological significance *(Aq 4.2, Terr__, Pk 3.0)* Important prey near bottom of food web. Community composition can indicate predation pressures. Zooplankton can help interpret aquatic productivity and biomass patterns.

Management significance *(Pk 1.2)* There was little discussion at the technical committee meeting.

Measurability/Sensitivity *(Aq 2.7, Terr__)* Requires taxonomic expertise and can be costly; annual August sampling may be sufficient.

#34 Terrestrial invertebrate communities - *Measures* include species composition and abundance.

Ecological significance *(Aq 2.0, Terr 3.2, Pk 3.7)* Invertebrates affect decomposition rates and mycorrhizal associations. Pollinators are ecologically important and parasitoids are an important prey base.

Management significance *(Pk 2.2)* Most concerns are related to pests and exotics. See indicator #35 and 42.

Measurability/Sensitivity *(Aq 3.0, Terr 2.0)* Standard methods exist, but they are labor intensive and require taxonomic expertise.

#35 Terrestrial pathogens and invertebrate pests (new indicator from Terrestrial/Wetland Workshop) - *Measures* include rates and area of infestation of defoliators, oak wilt, Lyme disease, West Nile disease, chronic wasting disease, *Armillaria*.

Ecological significance *(Aq__,Terr 3.9, Pk__)* is potentially huge since populations of pests can explode.

Management significance *(Pk__)* Impacts health and well being of biota, including humans. Disease (Lyme disease) and infestations can impact visitor experience. Large areas of diseased forest can be fire hazards.

Measurability/Sensitivity *(Aq __, Terr 3.0)* Tree ring and remote sensing data can be used. The group did not discuss the sensitivity of this indicator.

APPENDIX D

#36 Algae (changed from phytoplankton) - *Measures* are species composition, population change, chlorophyll a.

Ecological significance (Aq 4.1, Terr 2.7, Pk 2.9) Primary producers at bottom of food web. Provide an index of nutrient levels, and can help interpret patterns in primary productivity. Algae are highly significant in lake systems. See also indicator numbers #2 and #15.

Management significance (Pk 1.3) High algal growth decreases water clarity and can reduce dissolved oxygen to toxic levels.

Measurability/Sensitivity (Aq 2.8, Terr 2.3) Many algae are attached (periphyton) rather than planktonic, so plankton tows will yield skewed subset of species. Diatoms in surficial sediment cores may be the best overall measure of productivity. A surface water grab in August for blue-greens and scums may be worthwhile. Because turnover is fast, counting is not feasible, is labor intensive, and taxonomic expertise is required.

#37 Diatoms (added at the Air/Aquatic Workshop) - *Measures* include species composition and density of diatoms from surficial deposits and sediment cores, which provide current and historical water quality records respectively.

Ecological significance (Aq 4.3, Terr__, Pk__) Cores provide a good historical perspective of water quality parameters. A single, annual surface sediment sample is integrative of the population within a lake.

Management significance (Pk__) The technical committee did not score this indicator. The historical context is important for management to understand the limits of natural variability and triggers for action.

Measurability/Sensitivity (Aq 3.9, Terr__) Diatoms are sensitive to water quality parameters and are easily measured. A change in the diatom community indicates a change in the system. Large databases exist globally for comparisons. Taxonomic expertise is required.

#38 Lichens and fungi (added at Air/Aquatic Workshop) - *Measures* are species composition and abundance.

Ecological significance (Aq__, Terr 2.6, Pk__) They provide an important food source, microhabitat, and are crucial in many mycorrhizal associations.

Management significance (Pk__) The technical committee did not score, but lichens were suggested as indicators of air quality at scoping sessions.

Measurability/Sensitivity (Aq__, Terr 1.9) Standard methods exist but they are time consuming and require taxonomic expertise.

#39 Amphibians and reptiles (herptiles) - *Measures* include species composition, population change, habitat distribution, percent deformities, number of egg masses. Snapping turtle eggs are good indicators of toxics.

Ecological significance (Aq 3.8, Terr 3.9, Pk 4.1) Major vertebrate group that drives many food webs and has high biomass. Good integrator of aquatic and terrestrial ecosystems. See also indicator #47.

Management significance (Pk 2.9) Some parks referenced direct management decisions relative to T&E species (INDU). Turtle nests sometimes need protection.

Measurability/Sensitivity (Aq 2.6, Terr 3.0) Sensitive to habitat loss, drought, habitat condition, toxins, Ultra-Violet light, fish stocking, and parasites. Many standard methods exist (call surveys, drift fences, cover boards), but some need to be evaluated for accuracy and some are labor intensive. Timing of monitoring is critical. Call surveys are of questionable value because of a high signal to noise ratio. The Natural Resource Research Institute is currently evaluating this indicator.

#40 Bird communities - *Measures* include species composition, distance to individuals (for density estimates), population change, young produced/occupied area (productivity).

Ecological significance (Aq 3.6, Terr 3.9, Pk 4.2) Birds account for high biotic diversity (60-65 percent of vertebrates), and contribute to seed dispersal and the control of pest populations. They are also disease vectors and spread exotic plants and animals. Some corridors (Mississippi and St. Croix rivers and Great Lakes shorelines) act as major flyways so that measures of bird use can represent species abundance across large regions. May be indicators of habitat change. Presence/absence of certain diving ducks can indicate changes in food sources. Birds are mid- to high-level bioaccumulators, and integrate aquatic and terrestrial environments.

Management significance (Pk 3.6) Birds are of high interest to the public (charismatic fauna). Several species are T&E or otherwise of special concern. Neotropical migrants, grassland birds, and shorebirds are groups of special concern.

Measurability/Sensitivity (Aq 4.0, Terr 3.4) Standard methods exist (BBS, point, and distance counts for land birds, aerial surveys for eagles and waterfowl, boat surveys for loons) and there are abundant baseline datasets. Fieldwork can be labor intensive and is best done by the same observer(s) each year. Observers must be accomplished at identifying birds by sight and sound and need to collect habitat data. Equipment needs are minimal. Shorebirds are sensitive to shoreline development. Certain species are sensitive to habitat change though it can take many years to tease out variability.

#41 Mammal communities - *Measures* would include species composition, population size, and demographics.

Ecological significance (Aq 3.8, Terr 3.2, Pk 3.3) Small mammals are prey base for higher trophic levels and cyclic abundance can have a boom and bust effect on other organisms (e.g., microtine cycles can drive raptor and some mesocarnivore populations). Small mammals are seed dispersers and disease vectors. High level carnivores can effect prey abundance, demographics, and composition (i.e., wolves on white-tailed deer or moose). Beaver, as a keystone species, alter the landscape. River otter, mink, and muskrat bioaccumulate toxins and are known indicators of contaminants.

Management significance (Pk 2.7) Hunting and trapping can be issues in lakeshores and riverways. Mammals can be of high public interest and as such can serve to focus attention on ecological problems. For problem and T&E species, see indicator numbers #43 and #47.

Measurability/Sensitivity (Aq 3.4, Terr 2.7) Many standard methods exist including mark recapture, DNA sequencing, aerial surveys (beaver, moose, wolf), and tracking or sign indices. Hair samples can be used for Hg and other heavy metal analysis. Many datasets exist, both for contaminant studies and for general population studies, for comparison purposes. State agencies monitor some populations but rarely with sufficient intensity to assess park populations.

#42 Plant and animal exotics/invasives (split from problem species at the Air/Aquatic Workshop. Note park scores are included in problem species, #43) - *Measures include* distribution and abundance, surveillance and early detection, results and consequences of control efforts.

<u>Ecological significance</u> *(Aq 4.7, Terr 4.9, Pk__)* Some species have huge impacts, such as zebra mussels and purple loosestrife. They can alter trophic relations, change biological diversity, threaten native biota, and alter water quality. Some are highly integrative (e.g., exotic salmonids contribute large quantities of biomass as they move upstream and die). Domestic dogs and cats can negatively impact wild canid and bird populations, respectively.

<u>Management significance</u> *(Pk__)* Of high interest to managers. EPMT formed in response to management concerns. There are specific NPS mandates to manage exotic species.

<u>Measurability/Sensitivity</u> *(Aq 3.9, Terr 3.6)* Other groups (state DNR, FWS) are monitoring exotics, so some data are already available. Good protocols exist for most species. Remote sensing techniques are applicable in some cases. Monitoring of plants could be coordinated with EPMT or done in tandem with a plant community monitoring protocol. A surveillance/advance warning system could be implemented via visitor participation.

#43 Native species out of balance (previously titled problem species) - *Measure* abundance, demographics, herbivory and predation rates for species such as stocked native fish, white-tailed deer, raccoons, skunks, aquatic macrophytes, and algae.

<u>Ecological significance</u> *(Aq 2.8, Terr 3.9, Pk 4.3)* White-tailed deer can have chronic impacts on vegetation leading to the alteration of the composition and structure of forests. Deer can also have huge impacts on certain threatened, endangered, and sensitive species. Stocking native fish species alters the gene pool and can disrupt movements and behaviors of local stock. Excessive growth of aquatic macrophytes can alter habitat and choke waterways. Algal blooms can alter water quality for fish and other species.

<u>Management significance</u> *(Pk 4.4)* Closely tied to ecological significance (e.g., deer browse has impacted management decisions).

<u>Measurability/Sensitivity</u> *(Aq 2.9, Terr 3.1)* Methods for measuring these species are highly variable. Some are relatively easy and standard protocols exist. Aquatic macrophytes and algal blooms are sensitive indicators of nutrient enrichment and eutrophication.

#44 Harvested species - *Measure* population change, numbers or biomass harvested for species such as fish, turtles, game birds, bear, deer, furbearers, timber, medicinal and edible plants.

<u>Ecological significance</u> *(Aq 4.0, Terr 2.8, Pk 2.9)* Impacts of harvested species on ecosystem are not well studied or understood, but can be huge. Local over-harvest can affect recruitment and population dynamics.

<u>Management significance</u> *(Pk 3.2)* Fishing is a major draw of visitors to parks, and as such, has huge impacts. Harvest of animals outside park boundaries can impact park biota. Treaty rights (hunting, fishing, ricing) can be issues in certain parks. Information can be important for asserting management concerns and responsibilities with state DNRs and tribes.

<u>Measurability/Sensitivity</u> *(Aq 3.2, Terr 2.7)* State agencies monitor most harvested species, but estimates are rarely accurate for park populations. Harvest of migratory waterfowl is not indicative of local population change. Turtles are rarely monitored. Methods of monitoring fish harvest have known biases in less sampled areas (parks).

#45 Terrestrial plant communities - *Measures* include floristic, structural, and age composition; amount of coarse woody debris.

<u>Ecological significance</u> *(Aq__, Terr 4.4, Pk 4.1)* Plant communities are the key habitat component and the functional basis for terrestrial ecosystems. As primary producers they are

important conveyors of energy. Plants can be used to identify special habitats and are integrative with indicators #12, #13, #18, #19, #23, #25, #39, #41, #43, and #44).

Management significance *(Pk 3.8)* Often requires cooperation with other agencies for forest health monitoring, control of exotics, and fire management. Visitor use can impact vegetation.

Measurability/Sensitivity *(Aq__Terr 3.6__)* Standard techniques are available, both on the ground and remote, but they can be time consuming and require taxonomic expertise.

#46 Aquatic and wetland plant communities - *Measures* include species composition, area of cover, structure, distribution.

Ecological significance *(Aq 4.4, Terr 4.6, Pk 3.8)* Plant communities are the key habitat component and the functional basis of aquatic/wetland ecosystems. They provide substrate, habitat, and structure; help to stabilize the substrate and prevent the spread of exotics; and are highly productive micro environments.

Management significance *(Pk 2.6)* Concerns regarding loss or degradation of wetlands and littoral areas due to water level fluctuations, development, and visitor use. Tied to indicator numbers: #13, #14, #28, #42, and #47.

Measurability/Sensitivity *(Aq 3.4, Terr 3.6)* Aquatic plants are sensitive to water quality, lake level fluctuations, climate warming, and drought. Emergent vegetation cover can be monitored remotely and hydroacoustics are beginning to be used for mapping submergents. Standard protocols are developed at different scales. Monitoring can be time consuming.

#47 T&E species - *Measures* include area, numbers, vigor, percent of biota, community composition.

Ecological significance *(Aq 3.9, Terr 2.7, Pk 3.7)* T&E species contribute to biodiversity.

Management significance *(Pk 4.6)* Parks may be islands for maintaining some of these species. The overall significance varies by species.

Measurability/Sensitivity *(Aq 2.3, Terr 2.1)* These species may be sensitive to changes in their particular habitat, though often they are difficult to find and monitor, and small sample sizes make statistical analysis difficult. Monitoring would have to be tailored to individual parks and may not be efficient at the Network level.

#48 Biotic diversity - *Measure* the total number of species, often for defined taxonomic groups such as “vascular and nonvascular plants”) per unit area.

Ecological significance *(Aq 1.8, Terr 2.1, Pk 3.9)* Native biodiversity is important, and high diversity can indicate a functional ecosystem.

Management significance *(Pk 2.7)* Important areas can be targeted for protection.

Measurability/Sensitivity *(Aq 1.3, Terr 2.6)* Diversity as a measure is not very useful. Unless an IBI is developed, each species (including each exotic) is equally important. Due to issues of scale, diversity may be difficult and costly to measure and interpret. Diversity is important, but not necessarily a sensitive indicator and it can be derived from other measures.

APPENDIX E

Initial list of 40 candidate Vital Signs with examples of measures, supporting models, and supporting parks. This list was the result of Network staff deliberations and a meeting with the Network Technical Committee in September, 2003.

Category Attribute suites (aka Vital Sign)	Examples of measures	Supporting models	Parks identifying as issue from scoping workshops
Water quality			
Core water quality suite	Temp, cond, pH, DO, flow level, PAR, Secchi, turbidity, N, chloride	IL, W, LR, GL	APIS, MISS, SACN, INDU, SLBE, GRPO, PIRO, VOYA, ISRO
Advanced water quality suite	Bacteriological, chemical, nutrients, light/temp.	IL, W, LR, GL	APIS, MISS, SACN, INDU, SLBE, GRPO, PIRO, VOYA, ISRO
Sediment analysis	Nutrients and contaminants	IL, W, LR	
Contaminants			
High trophic bioaccumulation	Loads in: fish, bald eagle, otter, snapping turtle eggs, or colonial waterbirds	IL, W, GL	
Health, growth and reproductive success	% reproductive success, % tumors…in same organisms as above	IL, W, F, GL	
Air quality	Atmospheric deposition of contaminants		APIS, INDU, GRPO, SLBE, VOYA,ISRO, PIRO
Toxic concentrations in water	Loads in waste water and surface water	W	APIS, MISS, SACN, INDU, VOYA, ISRO
Landscape, Land Use Change			
Air quality related values (smog)	Particulates, view-shed, smell		Added in Committee discussions
Land cover coarse scale	Forestland cover, 5 fragmentation, patch size	W, LR, F, EP	APIS, MISS, SACN, VOYA, INDU. GRPO
Land cover fine scale	% hardened shoreline, # artificial structures	W, LR, F, EP	APIS, MISS, SACN, INDU, VOYA, PIRO
Land use coarse scale	Urban density, current and historical human use, patterns such as agriculture, forestry, etc.	W, EP	APIS, MISS, SACN, PIRO, GRPO, SLBE, VOYA.
Land use fine scale	Density of campsites, trails, roads, other visitor use facilities	W, EP	APIS, MISS, SACN, INDU, SLBE, VOYA., ISRO, GRPO, PIRO
Ecosystem processes			
Water level flucuations	Lake levels, stream flow and stage	IL, W, LR, EP	APIS, VOYA, ISRO
Nutrient dynamics	Land/water decomposition rates and microbial	W, F, GL	ISRO
Stream dynamics	Rate of scouring, erosion/sedimentation, channel	LR, EP	MISS
Primary productivity	Rate of carbon fixation	W, F, GL	
Succession	Rate of regeneration, replacement	F	APIS
Trophic relations	Rate of herbivory, predation rates	F	
Geological processes	Changes in beaches, bluffs, sandscapes	EP, W	APIS, SLBE, PIRO
Habitats			
Land-water transition zone	Suite of measures on physical and biological change of habitat and communities	IL	APIS, SACN, VOYA, SLBE, PIRO, ISRO
Soil characteristics	Moisture, temperature, nutrient levels	F, EP	Added in Committee discussions

APPENDIX E

Category Attribute suites (aka Vital Sign)	Examples of measures	Supporting models	Parks identifying as issue from scoping workshops
Special habitats	Adopt suite of measures depending on area		Added in Committee discussions
Weather and Climate			
Weather, meteorological data	Min., max. temperature, precipitation, extremes	IL	APIS, VOYA, INDU, PIRO, SLBE
Phenology	Dates of first flowering of water lily, leaf drop, ice	IL	APIS
Organisms, Species, Populations, Communities			
Fish communities	YOY, recruitment, composition	IL, LR, GL	APIS, MISS, SACN, ISRO
Benthic invertebrates	Composition of Diporeia, Hexagenia, oligochaetes	IL, W	APIS, SACN
Mussels and snails	Species composition, population change	LR	MISS, SACN
Sponges	Species composition, population change		SLBE, INDU
Zooplankton	Species composition, population change	IL, W, LR, GL	APIS
Terrestrial invertebrate communities	Changes in diversity, infestation rates, area		APIS, INDU, VOYA
Phytoplankton	Species composition, population change	IL, W, LR, GL	APIS
Herps	Species composition, population change	W	APIS, MISS, SACN, INDU, GRPO, PIRO
Bird communities	Species composition, population change	LR, GL	APIS, MISS, SACN, INDU, SLBE, GRPO, PIRO
Mammal communities	Species composition, population change (umbrella and keystone species - beaver, hare, sm. mammals)		APIS, ISRO, GRPO
Plant an animal problem species	Invasive and exotics (incl. W.t. deer) - % of flora and fauna, change in number or area	W, LR, GL	APIS, MISS, SACN, INDU, SLBE, GRPO, PIRO, VOYA, ISRO
Harvested species	Population change and numbers harvested (game,		APIS, PIRO, VOYA, ISRO
Terrestrial plant communities	Composition, area of cover, rate of change	LR, F	APIS, MISS, SACN, SLBE, GRPO, PIRO, VOYA, INDU
Aquatic plant communities	Composition, area of cover, rate of change	IL, W, LR	APIS, SACN, VOYA
T&E species	Area, numbers, vigor, % of flora and fauna		APIS, MISS, SACN, INDU, SLBE, PIRO, VOYA
Biotic diversity	Numbers of species pre unit area (include island	W, F	APIS, SACN

SCORING
5 = Very high priority
4 = High priority
3 = Moderate priority
2 = Low priority
1 = Very low priority
0 = Not applicable, score will be averaged
99 = No opinion, score will not be averaged

MODELS
IL = Inland lakes
W = Wetlands
F = Forests
EP = Earth processes
LR = Large rivers
GL = Great Lakes

PARKS
APIS = Apostle Islands NL
GRPO = Grand Portage NM
INDU = Indian Dunes NL
ISRO = Isle Royale NP
MISS = Mississippi NRRA
PIRO = Picture Rocks NL
SACN = St. Croix NSR
SLBE = Sleeping Bear Dunes NL
VOYA = Voyageurs NP